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CRISIS IN AMERICAN MATH, SCIENCE AND ENGINEERING EDUCATION

HEARING

OF THE

COMMITTEE ON LABOR AND HUMAN RESOURCES UNITED STATES SENATE

ONE HUNDRED FIRST CONGRESS

FIRST SESSION

ON

EXAMINING THE STATUS OF AMERICAN MATH, SCIENCE AND ENGINEERING

NOVEMBER 14, 1989

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CONTENTS

STATEMENTS

TUESDAY, NOVEMBER 14, 1989

	Page
Simon, Hon. Paul, a U.S. Senator from the State of Illinois, prepared statement	3
Pell, Hon. Claiborne, a U.S. Senator from the State of Rhode Island, prepared statement	4
Hatfield, Hon. Mark O., a U.S. Senator from the State of Oregon	5
Sagan, Dr. Carl, David Duncan professor of astronomy and space science, Cornell University, Ithaca, NY	10
Malcom, Dr. Shirley M., head, directorate of education and human resources programs, American Association for the Advancement of Science, Washington, DC; Dr. Irwin Shapiro, director, Harvard-Smithsonian Center for Astrophysics, Harvard University, Cambridge, MA; Dr. Leon M. Lederman, nobel laureate, director emeritus, Fermilab, Batavia, IL; and Lourdes Monteagudo, deputy mayor for education, City of Chicago, Chicago, IL	22
Prepared statements of:	
Dr. Malcom	26
Dr. Shapiro	47
Dr. Lederman	55

ADDITIONAL INFORMATION

Articles, publications, etc.:	
Why We Need To Understand Science, by Carl Sagan, from Parade Magazine, September 10, 1989	18

CRISIS IN AMERICAN MATH, SCIENCE AND ENGINEERING EDUCATION

TUESDAY, NOVEMBER 14, 1989

U.S. SENATE,
COMMITTEE ON LABOR AND HUMAN RESOURCES,
Washington, DC.

The committee met, pursuant to notice, at 10:02 a.m., in room SD-430, Dirksen Senate Office Building, Senator Edward M. Kennedy (chairman of the committee) presiding.

Present: Senator Kennedy.

OPENING STATEMENT OF SENATOR KENNEDY

The CHAIRMAN. The committee will come to order.

This hearing will consider the status of American math, science and engineering education. Throughout our history, Americans have excelled in these fields. We are still renowned today for our ability to translate scientific concepts into practical applications for the benefit of society. From the telegraph and telephone to the car and computer, American scientists and engineers have continued to set the world standard—at least until recent years.

Today, however, our foreign competitors are able to build higher quality products at lower cost. Japanese and German engineers translate American inventions into commercial products that increasingly dominate the global marketplace. Their businesses reap vast profits from innovations, and those profits are used to buy up American industry and real estate.

Our current problems stem in large part from our under-investment in human resources, which are the ultimate source of the Nation's strength and creativity. As a consequence, American students regularly finish last in comparison with their counterparts in other industrial countries.

Too many of our math and science teachers are not qualified in their subjects. One-third of U.S. high schools offer no physics course; many others offer no chemistry or biology courses. Even in schools that offer such courses, the results are not encouraging. According to a recent survey of 13 countries: U.S. high school seniors in advanced physics ranked ninth; in advanced chemistry, eleventh; and in advanced biology, dead last.

At the college level the situation is equally bleak. Less than one percent of last year's freshman class planned to major in math, compared with four percent 20 years ago. Currently, only five percent of U.S. undergraduates earn bachelor of science degrees, compared to 20 percent in Japan and 37 percent in Germany. In U.S.

graduate schools, about 50 percent of the engineer doctorate degrees are earned by foreign students.

Unfortunate as the situation is today, demographic trends suggest greater problems in the future. The National Science Foundation estimates that the Nation will face a shortage of 675,000 scientists and engineers by the year 2006.

We need to do more to encourage students to enter these fields, especially women and minorities. Encouraging education in these areas is no longer just a matter of equity; it is essential to maintaining U S. competitiveness in the global economy.

To meet the overall challenge, we also need more skilled technicians and a general work force with enough scientific literacy to handle advanced technologies.

According to a recent study by MIT, much of the success of Japan stems from the fact that its blue-collar workers can interpret advanced mathematics, read complex engineering blueprints, and perform sophisticated tasks on the factory floor far better than blue-collar workers in the United States.

When the MIT group testified before this committee last spring, they told us how Nippon Steel retrained 2,000 blue-collar workers when a steel plant closed, to take computer and other high-tech jobs in the company's new electronics division. That rapid transition was possible because of the workers' solid high school education in math and science.

America's lagging performance in these fields is a national disgrace. Failure to act now will lead only to greater problems in the future. The Nation that led the way to the moon cannot afford to fall behind on earth.

American children have just as much ability to excel in math and science as children in any other nation. That applies to women and minorities, too, if special efforts are undertaken to counteract the cultural impediments to their entering fields.

The problem does not stem from any lack of talent among American youth. The fault lies in our educational system and our community support structure. We need to address the entire spectrum of education, both formal and informal, from kindergarten through graduate school. We need to give special priority to women and minorities, to general scientific literacy, to technical training, and to recruiting students to become scientists and engineers.

I intend to introduce legislation to achieve these goals at the beginning of the next session, and today's hearing will focus on these needs that must be addressed.

Our witnesses this morning share a major commitment to improving the quality of math, science and engineering education in the Nation, and I look forward to their testimony.

The chart which we have up here is self-explanatory. It shows the percent of the NSF budget devoted to science and engineering education (SEE) and also shows the percent of engineering Ph.D's awarded to foreign students. What we see is that SEE dropped from nearly 50 percent of the NSF budget right after Sputnik to almost 0 in 1983.Since then we've bumped it up a little bit, quite frankly, on the insistence of Congress. We saw the excellent work of Senator Mikulski in this last appropriations cycle, increasing this function by about $10 million and receiving a note back from

NSF, complaining about Congress according that priority to education.

I must say that I at least draw the conclusion—others might not—that certainly in the early 1980s, given the mood in the country, particularly in the Executive Branch, resources were diverted to basic research rather than education.

And then we can see the corresponding increase in the percent of our engineering Ph.D's awarded to foreign students, of whom only about half remain in this country in any event.

At this point, we will include in the record the statements of Senators Simon and Pell.

[The prepared statements of Senators Simon and Pell follow:]

PREPARED STATEMENT OF SENATOR SIMON

Senator SIMON. Mr. Chairman, I am pleased to join you in welcoming this very impressive group of witnesses, and to take part in this hearing. We will hear today testimony on issues related to math and science education—a subject that is of critical importance to our Nation's future. Scientific literacy should be a central goal of education, but it is not. We need to challenge America's school children to achieve their full potential, and provide them with opportunities to develop their talents, especially in the areas of math and science.

Reform of education in science, math and technology is needed. There is much that is underway in many school districts across the country to improve science and math instruction in the schools. But, there is much more that can be done. I am particularly interested in learning more about effective school district strategies and individual school practices that are effective in reaching disadvantaged and minority students. These students represent a rich source of talent for our Nation—talent that we cannot afford to leave untapped.

I am pleased to welcome two of our expert witnesses today who are here to share with us some exciting initiatives underway in the Chicago Public Schools to improve math and science education. Dr. Leon Lederman, a distinguished nobel laureate, physicist and educator, is Director Emeritus at the Fermi National Accelerator Laboratory in Battavia, IL. He is also a professor of physics at the University of Chicago. Dr. Lederman has been a leader in the area of science education, and has initiated at Fermilab 15 educational programs for teachers and high school students. He was also instrumental in the establishment of the Illinois Science and Math Academy, a free public boarding school for gifted young people in Aurora, IL.

Ms. Monteagudo is a leader in the area of education in Chicago. She was named this year Deputy Mayor for Education, under Mayor Richard Daley, and had been an energetic force for change within the Chicago Public School System. I welcome both of you here.

Mr. Chairman, former Secretary Bill Bennett called the Chicago School System the worst school district in the Nation. But, the Chicago school reform initiative has generated a wave of enthusiasm and excitement that heralds a new day for education for Chicago's

school children. Chicago is now leading the Nation in its efforts to implement educational reform and improve the quality of education, particularly in math and science.

I look forward to hearing the views and suggestions of the educational leaders assembled here today.

PREPARED STATEMENT OF SENATOR PELL

Senator PELL. Mr. Chairman, the subject of today's hearing is one of extreme importance, and I am delighted to join with you and the other members of the committee to examine the condition of science and math education in our Nation.

I am disheartened and discouraged by the alarming statistics reflecting the level of science and mathematics proficiency held by our Nation's young people. We have heard the staggering figures time and time again. Fifty percent of high school students have limited mathematical skills; more than 50 percent are unable to evaluate procedures or results of a scientific study. In comparison with students from our industrialized counterparts in the world, American students score lower on math and science tests; they rank last in biology, next to last in chemistry and close to the bottom in physics.

As a result of this, the United States will face a shortage of at least 450,000 scientists and engineers by the year 2000. Our world is advancing technologically at an astronomical rate. We simply cannot afford to sit back idly and accept this distressing trend. Until we at the Federal level vow to put forth a committed effort to raise the level of math and science expertise our citizens command, we well surely continue to be deafened by these inexcusable numbers, and we as a Nation will suffer dearly.

The global atmosphere is one of competition. We are already losing ground. It is our job to fight—and fight hard—to regain that ground. We must forge ahead to provide our citizens with the tools necessary for the construction and maintenance of a strong and competitive Nation. This commitment must be more than one of words, it must be one backed by dollars.

At the first part of this decade I was one of the principle authors of the Education for Economic Security Act. This important program remains the chief Federal response to our poor showing in mathematics and science achievement. I had hoped that appropriations for this program would more closely match that of the authorization levels. To my mind, our response to this crisis must be as vigorous as our initial response to Sputnik's launch more than 30 years ago. Today, unfortunately, I am sad to report that we cannot make that claim. Appropriations for the math and science program have barely exceeded $100 million in any fiscal year. And I fear that this morning's hearing will tell the story of the ill effects of our failure to make a more significant investment.

I commend the Chairman for his efforts to continue our focus on the condition of math and science education. I look forward to working with Senator Kennedy and the other members of the committee to create a wave of excellence in math and science, and in every aspect of education.

The CHAIRMAN. We welcome now—and his timing is impeccable—Senator Hatfield, as our lead-off witness this morning.

Senator Hatfield has had a very diversified, distinguished public life, both in his own State of Oregon and in the Senate. He was a former college professor and has demonstrated a very strong interest and leadership in the Nation's education programs. So we are very appreciative of his presence here. We have had a good opportunity to work with Senator Hatfield in a number of different areas, and we look forward to working with him in the next session of this Congress. If we are going to be able to have an effective program, certainly his support on the Appropriations Committee will be invaluable to achieve the objectives which we will discuss during the course of our hearing today.

Senator Hatfield, we are delighted to have you here, and we look forward to your statement.

STATEMENT OF HON. MARK O. HATFIELD, A U.S. SENATOR FROM THE STATE OF OREGON.

Senator HATFIELD. Thank you, Mr. Chairman.

I appreciate the opportunity to be here this morning. I want to congratulate you for your continued and further leadership in the field of education, in addressing this very important issue of the diminishing person-power pool of math and science teachers, students, researchers, and all of the other of those activities associated with a math/science education.

Mr. Chairman, a few days ago we had a hearing over in the Governmental Affairs Committee, with Senator Glenn presiding, and I will repeat some of my testimony given at that time, but only to affirm the axiom that repetition is the first law of learning. And I don't think we can repeat the database upon which we are now confronted as we look for the solutions to replenishing this diminishing quantity and quality of young people going into the field of education, looking to math, science and engineering.

I'd like to start with one baseline, because I think it illustrates so many factors here that there is no one single action that I think that can take place that will correct the problem entirely.

We have historically depended on the white male 22 year-old for the resource or for the part of the demographics of this country to be our scientists, to be our mathematicians and our engineers. And as you look at the changing demographics of this country, we now find that 63 percent of the people 22 years of age are neither white nor male. So that this leveling out of that part of the demographics would illustrate the fact that we have to look far beyond the traditional source for such trained people.

In addition to that, it means that we have to do some compensatory educational programs, we have to do some very specially-targeted programs to tap in on the 22-year-old person who is not white or male. Now, we are not restricting that, of course, just to 22 year olds; I am only using this as an illustration.

The second factor that I think we have to realize is that as we move in a structural economic evolution to higher and higher technology, it means that in the private sector there is a growing demand for such trained persons.

I have used frequently, and I think it illustrates my point, that in the outstanding work of Hewlitt Packard, one of our outstanding manufacturers today in the world market, Mr. Young, the president, has indicated that over 50 percent of their products in the world market today are the result of the last three years of research and development, that again recognizes the fast-changing private sector that will have to have additional personnel to maintain competitiveness.

I found this experience in my own background as Governor of my State back in 1958-59 when we were suffering from a very severe recession. Mr. Chairman, we have a timber-based economy in our State. We have over 51 percent of my State owned by the Federal Government. We have the largest amount of standing timber of any State in the Nation. We produce more timber products than any other State in the Nation. As a consequence, we are kind of a monoculture, and when the housing market is down, so is our economy. And as Governor, I was hoping to try to diversify the economy, and in an analysis that was created out of a committee set up of academicians and scientists and business personnel, we determined that our real key to the future of diversifying our economy was to be found in the enhancement of our math/science programs, particularly in the postdoctoral area, where we were highly deficient in our system of higher education, and we went about the business of founding an Oregon Graduate Research Center, with private funding, and as a result of that, 25 years later, we find now that we are second to the Silicon Valley of California in the increase of high-tech industry—some 67 Japanese companies alone, which have established plants there, along with our own domestic growth—and plants the size of 1,700 to 2,000 employees, Fujitsu America as an example. And that in part was because we have put the focus where we felt that we had to develop the manpower, the womanpower, to diversify the economy, the educated persons.

I would also say that today over 55 percent of our doctorates given in higher education to engineers are given to foreign students. Almost one-quarter of our doctoral degrees are now awarded to foreign students in the various disciplines within science. So that again, we are losing in a lot of the competition from the private sector.

Third and last, as illustration, is the tremendous increase in the demand for medical research and medical science. Senator Kennedy, you again have been on this forefront, and you are very much aware of the enhancement of our research capacity through appropriating dollars as well as in developing facilities of brick and mortar. But we have to fill those facilities.

As you know, we have not hired a lead bench scientist at NIH for ten years because we cannot compete for those scientists. Today, we make a comparative study, and we find that the average scientist there makes $75,000 per year. Well, in academics alone, he can equate out that salary to $135,000 on the average. We used to be concerned about competing with the private sector. Now, that is a higher salary base in addition to what the academic differential is.

So we have this problem within the field of medical research. We set up a system of 11,000 training grants to try to train people and

attract people into medical science research through the NIH. We find now that in order to compete there with the stipends offered in other areas for such students and young people, we had to reduce that down to a little over 10,000 training grants in order to take that amount of money and increase the per-grant stipend.

I don't think we have to go into the recitation of all the tests that have indicated that our young people are not competing well with the foreign students in the Western industrialized nations and the Asian nations. Various and sundry tests have been given to indicate that. I think there is a fundamental reason for that, and that is that in our public high schools, we have seen a tremendous diminution of the offering of science and math courses.

We have approximately 25,000 public high schools today. Seven thousand of them have abandoned teaching physics; 4,000 abandoned teaching chemistry; 2,000 abandoned teaching biology, and those that are still teaching, about one-third of them, a little more than one-third of them, are offering laboratory courses of hands-on effort and activity which is so important to learning.

The hands-on cannot be overemphasized. In fact, the Soviet Union, as you know, Mr. Chairman, abolished their medical curriculum last year. They found that 40 percent of their graduates from medical school could not read an electrocardiogram because of the failure of the curriculum in the Soviet Union in medicine to be able to keep a hands-on laboratory kind of experience. They have revised that at a very high cost, the revision of medical education in the Soviet Union. And yet we are finding that in our own country, we are losing that kind of experience of hands-on, of the applied science knowledge.

I also think one ought to look at those who are still teaching those courses because in the middle schools, 75 percent of those math/science teachers cannot be certified; they are not qualified to be certified by their certification agencies. Fifty percent of our high schools today teaching math and science are not certified.

Early last year, I started a number of meetings with various groups. We had luncheon meetings at the National Science Foundation, the National Science Adviser, the Academy of Sciences people all participated. One of the first we had was the military-industrial complex. We invited some of the largest defense contractors, and we invited some of the research university people, and we had a mix there, a very interesting mix. It is a deep concern of those who are involved in the military-industrial activities of this country. As you know, about 100,000 scientists today are involved in SDI research alone, and they take up a large percentage of our diminishing pool of scientists.

Then we had a meeting with the certification agencies in the elementary/secondary programs of our Nation. We had meetings with, as I said, the academies, the associations representing our scientists both in the practicing field, in the teaching field and in the learning field. In every instance, they came up with the same dilemma: Where are we going to get the young people for the future?

It is now estimated that we could place 138,000 engineers every year, starting back in 1982 until 1995. Every year there is that kind of a demand.

We find also that if we are going to meet that demand that we are going to have to have 300,000 new teachers of math/science between now and 1995 in order to avoid a shortfall of 700,000 scientists by the year 2000.

These things are no longer something that are just statistics. These are realities that are facing us in every phase of our lives.

Unfortunately, when President Reagan was elected, he wanted to abolish the Department of Education which was, as I have indicated before, just the wrong signal to send out to our people in our private sector and academic sector and other places that are struggling with this problem. So we have introduced, Senator Glenn and others, a resolution establishing this as a national priority to send a different signal, to reverse the previous signal.

Also, coming soon to be completed, as you know, we have sent to you and others copies of a bill that we have been working on to set up nine regional centers—well, first of all, to set up a coordinating office in the Federal Government to be headed by the National Science Adviser to the President, to coordinate all of the various agencies of the Federal Government that are involved in this subject field.

Second is a bill to establish nine regional agencies at the elementary school level, focusing in on the elementary, starting at the base of our public school systems. In that program, we hope to coordinate all of the resources within those regions—private, public, school and other groups—in being of assistance to those regions on how to enhance their elementary educational program. This will also include the nonformal type of educational resources. We have added money in the appropriations to the Spacemobile, to send a fleet of ten out. We have the Oregon Museum of Science and Industry, and other States have these independent agencies and programs that could be coordinated.

We would hope to be able to set up also money that would provide model programs, test case programs. We don't expect to have a single program that is going to apply everywhere throughout the country. We want to see the local regions develop their own. That, we feel, can be very helpful especially with a clearinghouse center to assist them from the Federal level. We would have moneys to be granted to enhance the informal educational resources as well as the nine centers.

Mr. Chairman, this is not a panacea. This is but a small step. But it seems to me it is necessary for that kind of a leadership role to be quickly established by the Federal Government, and I am very hopeful that this committee, along with its rich resources of experts and expertise, experience, can be helpful in this. I know that there is an omnibus bill that is being drafted to deal with some of the problems of education. I do feel the math/science does provide us with a very specific urgency, and it is something that we ought to approach with some kind of a beginning plan—and I emphasize the term "beginning"—but it is an important beginning.

I welcome this opportunity, and I am very happy to answer your questions.

The CHAIRMAN. Thank you very much, Senator Hatfield.

Part of the problem—and I think you alluded to it—is that many of the U.S. citizens receiving Ph.D's in science and engineering—

especially those in engineering—are going into military research and development.

Senator HATFIELD. Research follows the bucks is an old saying. And when you look at the fact that the Federal Government today is appropriating about $2 billion a year in military research and about $2 billion in medical, and when you begin to look at where so much of the military is going, it is going to higher salary-level areas and to more attraction. So that it is like a magnet, attracting more in that direction.

The CHAIRMAN. There are also, as I understand, various science-engineering educational programs at the Department of Defense and the Department of Energy that could be expanded and enhanced at the present time, while we are looking into the more basic questions which you raise.

Some have talked about developing an educational trust fund. That has been considered by some of the people on this committee, perhaps taking a certain percentage of the cutbacks in various weapon systems, for example, at DoD. Perhaps you could even broaden it—drawing the line at all Federal purchasing, putting a very small percentage of Federal procurement aside into some kind of an educational trust fund.

We have done it in terms of highway trust funds, we have done it with airport trust funds. I know what the problems are in terms of the Appropriations Committee and the Finance Committee in dealing with some of these issues. But do you think that given the scarcity of resources, that we ought to be trying to think a bit about some of the financing mechanisms so that we could at least be assured that these programs are going to be adequately funded?

Senator HATFIELD. Mr. Chairman, I think it is a very, very good idea to address the philosophy that if you are drawing out of a limited resource you should be doing something to replenish that resource. I have felt that we ought to have a surtax, frankly, on every budget that uses personnel out of the scientific community, that they are in effect reinvesting in that community from which they are drawing the resource.

Carrying that to an example, last year, Senator Nunn and I added an amendment with his support to the Appropriations Committee on the defense bill, in which we set aside $10 million for graduate research and graduate fellowships. We have created 150 per year. We did that as a line item. Then this year, Senator Nunn as Chairman of the Armed Services Committee authorized that as a permanent part.

Now, $10 million is but a drop in the bucket, but the point being that agriculture, the various natural resources, energy, are drawing out of these limited pools, and I feel that their budget ought to have a percentage, as you point out, a small percentage that would be set aside for graduate programs or for educational research to again train and intrigue or entice others into that field. Yes, I think it is an excellent idea.

Now, when you talk about an educational fund, I think it ought to be done within each agency to get as broad a base as possible of these agencies, understanding their dependency upon quality and specialty of education.

Mr. McGeorge Bundy wrote an article many years ago in the Saturday Review in which he talked about the indivisibility of education; we artificially divide it, usually because of the governing bodies, elementary, secondary, and so forth and so on. He said that really, education cannot be divided because a weak link in any part of it is of course a threat to all.

I think one of these days, I'd like to see an educational fund that would be a pooling of all these agencies, and maybe that's the way to start it out. But nevertheless I think we do have to begin to understand that idea of the indivisibility of education as well.

The CHAIRMAN. Well, we welcome your input in both building on what has been the excellent suggestion that you and Senator Glenn have been involved in, and second, perhaps thinking even in broader terms on this whole issue, recognizing there are so many different facets of it, and third, how we are really going to go about in terms of funding that program, because I think you certainly know the scarcity of resources.

I think you have made a number of excellent suggestions. We'd like to work with you as we develop those concepts, and we are very grateful to you for the time and clearly the amount of thinking that you have given to this issue. We are very grateful to you. Thank you very, very much.

Senator HATFIELD. Thank you, and Mr. Chairman, I congratulate you on an outstanding list of witnesses to follow. You have really tapped in on some of the outstanding leadership in our country today, and I appreciate their time and effort because many of them are giving up important time to come and give their opinions to these committees, and I think it will be invaluable for us.

The CHAIRMAN. Thank you very, very much.

Our next witness is Carl Sagan, world-renowned astronomer, author and educator; David Duncan Professor of Astronomy and Space Sciences at Cornell; recipient of innumerable scientific awards; better-known to the public for his Emmy and Peabody award-winning TV series, "Cosmos", which has been seen in more than 60 countries by 400 million viewers. He has also been awarded the Pulitzer Prize for Literature.

We are delighted to have you here. You are an old friend as well. A number of years ago, Senator Hatfield and I talked about nuclear winter in a meeting which included Dr. Sagan, a distinguished group of American scientists, and Dr. Velikov and a group of Soviet scientists over in the Caucus Room. It was a fascinating session which had a really important and profound impact on the thinking of certainly the Congress and the American people—indeed on people worldwide.

We are delighted to have you, Dr. Sagan.

STATEMENT OF DR. CARL SAGAN, DAVID DUNCAN PROFESSOR OF ASTRONOMY AND SPACE SCIENCES, CORNELL UNIVERSITY, ITHACA, NY

Dr. SAGAN. Thank you very much, Senator Kennedy. I am happy to be here.

In the interest of time, maybe I can insert into the record this article in Parade Magazine called "Why we Need to Understand Science".

The CHAIRMAN. It will be so included.

Dr. SAGAN. Maybe I can just give a brief summary to allow time for questions of my general perspective on the matter.

I don't have to go through the statistics. Senator Hatfield has already referred to them. But they are so tempting and excruciatingly awful, let me just mention a couple of things.

As an astronomer, maybe the key discovery for me was that less than half of all Americans know that the earth moves around the sun and takes a year to do it. I don't mean children; I mean adults, everybody. Now, of course, you can get through your life very well without knowing this. On the other hand, it is a fundamental aspect of our existence, and it is amazing to me that it is possible to get through the American school system without having encountered this fact. I know Professor Shapiro will present some other examples of what we don't know. It could take the whole morning to summarize——

The CHAIRMAN. Yes, taking this opportunity of talking about ridiculousness, I remember Russell Long's old story about a certain parish down in Louisiana. The school board was equally divided between those who believed that the world was round and those who believed the world was flat. So they had the various teachers come in. Those teachers who would say that it is round, the board members who believed it was flat would find them unacceptable; and the teachers who said it was flat, the board members who thought it was round found them unacceptable.

So finally, after going through the whole day, they came to the final nominee, and they asked him the question, and he said: "I can teach it round or I can teach it flat. You tell me which way you want it taught." [Laughter.]

Dr. SAGAN. Right, a kind of microcosm of the creationism debate among other things.

In tests of average 17-year-olds in many world regions, the U.S. ranked dead last in algebra. On identical tests, the U.S. kids had an average grade of 43 percent; their Japanese counterparts, 78 percent. In my book, 78 percent is pretty good, C-plus, maybe even a B-minus; but 43 percent is an F, and we are failing. And as one American newspaper headline said not too long ago, "We stink in science."

The best of 20 fifth grade classrooms in Minneapolis was outpaced by every one of 20 classrooms in Sendai, Japan, and 19 out of 20 in Tapei, Taiwan. South Korean students were far ahead of American students in all aspects of mathematics and science. Thirteen year-olds in British Columbia outpaced their U.S. counterparts across the boards—and so on.

I think there is no question that in science and mathematics, the United States is doing abysmally poorly.

There are two key questions. One is so what? In what way does it matter? And the other is what can be done to fix this situation. And let me say just a few words about each.

The idea of saving money or saving effort or doing nothing for bureaucratic reasons about education is a classic example of eating

the seedcorn. We may save a little something this winter, but next winter, having no seeds to plant in the interim, there is nothing to eat. It is a battle between the short term and the long term, and there are always political pressures to go with the short term and leave the long term for the next administration, the next tour of duty, the next session of Congress. This is just immensely foolish. We live in a society in many respects deeply dependent on science and technology and yet have arranged a situation which hardly anyone understands science and technology. This is a clear prescription for disaster.

There are at least four areas where knowing science, having—a current term—scientific literacy, is clearly important. The one that is most talked about is in jobs, profits, health of the economy, international competitiveness. And there also, the number of horror stories is really striking. Furniture companies which are otherwise economically healthy but have to go out of business because they can't find entry-level personnel who can do the simple arithmetic necessary to be a joiner. There was a major electronics firm which found that 80 percent of applicants could not pass a fifth grade mathematics test—and that is an American, not a Korean, fifth grade test.

U.S. industry is estimated to spend $25 billion a year right now in remedial education and lost productivity because of this issue, and that is probably an underestimate.

So in these strictly economic terms, it is very clear that something has to be done.

Second, there are a wide range of urgent issues that require the public and the Executive and Legislative Branches to understand something of science and technology in order to make the decisions. Consider the issue of global environmental effects, greenhouse warning, depletion of the ozonosphere, acid rain. Here is a case where policy and science interact, where what many are saying has to be done is expensive, has propagating political consequences. How can we make intelligent decisions on such issues if we don't understand the science and technology that underlies these issues? There will always in every such case be a temptation to dismiss, to temporize, to say let's make some more studies, and the danger is that in that period of time the problem gets much worse, and the solutions become much more inaccessible or at least much more expensive.

That is another way that is important, and not just that we produce more scientists and engineers, but that scientific literacy is widely dispersed through the American population and particularly in the halls of government.

Third—this is an intangible, but I think it is very important—humans are intelligent. That is our hallmark as a species. We are not faster, stronger, better camouflaged, better diggers, better swimmers, et cetera, than all the other animals. What we are better at is thinking. Thinking is our birthright. And the quintessential example of human inquisitiveness, human intellectual ability, is science. There are many others, of course, but science is absolutely key and characteristically human. We use it to understand the universe, to understand our origins, to understand ourselves. To deprive people of an understanding of science is to deprive them

of their birthright, to take away something that is fundamentally human. This is an intangible, but I think nevertheless a very important point. People want to understand the world, and if they don't understand science, they don't have a good chance of understanding the world.

Finally, the fourth reason in my view is the fact that science is much more than a body of knowledge. Science is a way of thinking. It is a way of approaching data, and the precepts of science are well-known. Arguments from authority have almost no weight because famous smart, respected people have made mistakes. Quantitative thinking is an excellent way to distinguish the wheat from the chaff. It is important to carry alternative working hypotheses in your head and see which on best matches the data, rather than imposing your preconceptions upon the world, and so on.

Now, sometimes these precepts of science are not fully utilized by the scientific community, but there is no question that they are the goal, the ideal.

This kind of thinking is not so widely used in other areas of human activity—economics, religion, social issues, or politics. I believe, considering the wide range of extremely serious problems facing our Nation and our species, that this kind of thinking is really essential. But this kind of thinking also worries lots of people who have drawn conclusions or accepted verities and do not want them challenged. This is borne out by many of the letters I got from this Parade piece. There are people who are uneasy about science because they are worried that scientific thinking will challenge values that they hold dear, and they don't want to be challenged. This is a deep and I think insufficiently examined part of the resistance to understanding science better.

Let me say a few things about how to approach this issue. First, I think it is very clear this must be approached on many different levels at once. It is not enough just to approach elementary schools or high schools or colleges and universities. We have to do this on all levels; we have to not only produce more expert scientists and engineers, but we have to increase the level of scientific literacy in the population at large, and we have to make it acceptable to communicate the joy of scientific thinking, and this includes the mass media.

I am astonished of how many of the letters I got from teachers and parents and students criticized the background, the preparation and the competence of teachers in science. Many reasons can be given, but there seems to be a widespread sense that people who are teaching science are not fully comfortable with science, are not fully prepared, have great anxiety themselves about science, are put off when their students ask intelligent scientific questions. And if the people at the very focus of teaching science feel uneasy about it and don't fully understand it, we clearly have a deep problem.

So better training of teachers, better remedial education of science teachers, summer schools, seminars, scholarships for teachers, and another very important aspect is money for laboratories in the schools. It is not enough just to read things out of a book or to see an audiovisual presentation. If you are to learn science, you have to have some hands-on experience. Laboratories are expensive; there are insurance questions; there are all sorts of reasons for put-

ting it off, letting the laboratories decay, letting the equipment degrade. Yet I think it is clear that this is a vital aspect.

There is an issue concerning scientists themselves. Most professional scientists do not public education in science on any level, and yet they are the people who have mastered the content, and it is not impossibly difficult to explain what you do if you are a scientist to the general public. There ought to be incentives and encouragement for professional scientists to spend part-time teaching in schools, to make themselves available for radio and television, to give lectures to the public, to write popular articles.

There is a need for the best scientists to devote some time in writing textbooks. The Soviet Union does this very well, the United States not nearly so well.

There is a major question about the media. I'm not just talking about the "mad scientist" image on Saturday morning cartoons for children, although I think that does enough damage. I am talking about the fact that there is virtually no science at all on television. There are some things called "science", but when you look at them, they are technology and medicine. Science, a scientific discovery for its own sake, with some description of what it is about, is virtually nonexistent in commercial television. Or, consider the newspapers. Almost every newspaper in America has a daily astrology column. Astrology is bunk. It is a fraud. It is, among other things, about 3,000 years out-of-date. They don't even know which constellation is rising when an individual was born. They have neglected the procession of the equinoxes. I need not give a diatribe on the deficiencies of astrology. But think—every newspaper in America, with one or two exceptions, has a daily astrology column. How many of them have even a weekly science column—how about a daily science column?

I think any visitor from the outside, looking at what is discussed and what isn't, will have no difficulty understanding why science education is not up to snuff in the United States.

There is, as far as I know, not a single television drama in which the hero or heroine is someone dedicated to understanding how the universe works.

Where are the role models? Where in the popular culture is science encouraged, or are kids encouraged to become scientists? Is anything like the joy of discovery of science presented to the American public? I recognize that media decisions are not within the purview of congressional legislation, but I nevertheless think that there are ways of encouraging the media.

There is the possibility of having promotion and salaries in the teaching of science at all levels be proportionate to competence. That does not always seem to be the case. And then finally, a question which I think is really important that relates to something I said before is the general question of respect in the schools for thinking, for asking hard questions, for asking questions that the teacher doesn't know the answer to. This is at all levels—maybe not so much in college—discouraged.

There is also enormous peer pressure in junior high school and high school not to excel intellectually. It is all right to excel in athletics, but not intellectually. What newspapers that publish details of the sports successes of the local high school teams publish the

outstanding science student in a particular internal competition in the schools? Look at the disparity between the societal rewards offered to students who are good in athletics and students who are good in science. It is not hard to understand.

But beyond that, there is a pervasive sense that people who excel intellectually in the high schools are somehow discourteous to their peers, somehow embarrassing to their peers. Because peer pressure is so powerful in pubescent and postpubescent times, this is an extremely powerful force, which I think could be countered if we had the will to do so.

Well, one of the most interesting aspects of writing this article in Parade—Parade has 65 million readers, so you get a lot of letters. I haven't read all of them, but I've read a representative sampling, and there is no question that there is a huge concern about this issue in America and lots of people who have constructive, some not so constructive, suggestions about what to do about it.

I think there is a great deal of support at all levels in American society for doing something serious about improving science education, scientific literacy, and the general attention given to things scientific.

Thank you, Senator.

The CHAIRMAN. Thank you very much, Dr. Sagan. You covered many, many areas in your commentary. These attitudinal questions, and how much we can do on those, are always a difficult challenge.

One other area I might mention is the lack of scientists involved in public policy issues. I was one of six the last time who voted for the pay increase, and I was inundated with letters from Massachusetts. I don't think I got one letter from a scientist urging an increase. And given what Senator Hatfield said as to the state of affairs at NIH, where there has been some real question in terms of intramural research, and what is happening at FDA, with a budget of effectively $500 billion a year, one-third of all consumer products—they haven't been able to hire new researchers in ages. We have seen tragically what has been happening out there recently.

But as someone who comes from a State which has a very large contingent of scientists and engineers and a record of excellence in terms of scientific research, the real lack of scientists and engineers involved in public policy constantly amazes me. I think increasing their participation in public policy is an important part of a long and lengthy list of things which are necessary. We must find ways to stimulate them to become much more involved in public affairs. And we need to stimulate the press to be more sensitive to these issues.

Let me ask you this. After Sputnik, we saw this country respond in a wide range of different outreach programs, energizing the whole area of science and scientific achievement. Are we going to have to have that kind of dramatic event every 20 years to keep us moving on this? How are going to keep the prop underneath this whole commitment? Is it going to be just narrow self-interest, that if we don't do it, we're not going to be able to compete?

What do you think, as someone who has obviously followed the interests of our country in science and science education over a period of time, when we have been the most effective in addressing

this issue, what have been the elements in our society and in our culture that have been responsible, and how are we going to get those elements back into our common experience?

Dr. SAGAN. Well, it is always convenient to have a demon from the outside to motivate us here. And we had one at the time of the launch of Sputnik, and it was very easy to get everybody's attention. This is true not just for science education, but across the board. One of the problems the United States is going to have to face if present trends continue is that the Soviet demon isn't there, and we're going to be desperately in need of an enemy in order to keep things focused. I am worried that we will go out, trying to find out. That is a parenthetical remark. I think it is unlikely that there will be one critical event that will motivate us. We will find a steadily deteriorating economy. We will find other countries doing better on test performances and economies booming.

I think we cannot expect that we'll be saved by an exogenous event. What we need is a kind of leadership. I would think a President who was comfortable with science, who encouraged science, who was known to talk to scientists, could do a great deal. There was a time, starting in the Eisenhower Administration and continuing through the next two administrations, when there was a vigorous, highly competent President's Science Advisory Committee. Not only did they do a great deal of good in the advice they gave; they also provided a sense that scientists—this now cycles back to your previous question—were involved in policy matters. It encouraged other scientists to say, "My goodness, there is a place where scientists, people I know, are involved in the policy apparatus, they can get through, their opinions can at least be heard—I'll spend some time doing that."

Right now—by "right now", I mean the last 10, 12 years—there has been a sense that that is not the case, that it is pointless for scientists to try to involve themselves in policy matters because no one is listening, and any departure from the conventional wisdom will be dismissed out-of-hand, therefore, why make the effort.

The CHAIRMAN. Let me ask you just a final question because I want to hear our other witnesses. What should we be expecting from scientists to try to make their subject matter interesting and relevant, versus what are the essential elements you've really got to understand in order to be able to be competent? Yesterday I was up at the McCormick Middle School in Columbia Point outside Boston. They get a grant of about $300,000 from the Bank of Boston for computer-aided education. Not only were 11-year-old children showing me how to do fractions and so on, but they were demonstrating how the kind of peer pressure that exists in our school system and inhibit individual achievement and advancement. We also went out about a month ago to Prince George's County, to one of the best high schools in the county, and when we walked in, the students said, "Do you think we're all nerds like everybody else does?"—because they are excelling.

What should we expect from the community? Should we not just be teaching in the old ways? Or do we have to teach it in the old ways in order to develop the kind of competency necessary to deal with some of these things? Can you put that in some perspective for me?

Dr. SAGAN. The way I view it, Senator Kennedy, is like this. Occasionally, I have an opportunity to teach a class in first grade, plus or minus one. And what I have found—and this has been true for the last 30 years since I've been doing this—it is anecdotal, but it is absolutely unchanged—is that these kids are scientists. They ask the right questions. They are not the least bit embarrassed when they don't understand the answer. They ask follow-up questions. Their range of knowledge is startlingly good. They are quick to learn. You have a sense of a whole classroom full of potential scientists.

Then you talk to kids in high school, and it is exactly the opposite. Everyone is concerned about social approval; sidelong looks to see how the person asking or answering the question is doing; there is a real fear of asking a "dumb question". There are no follow-up questions. The joy of learning has kind of gone out of them. Something has happened between first grade and high school, and it's not just puberty.

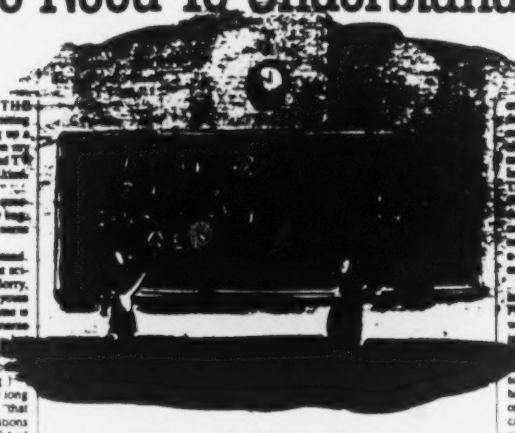
The schools are not encouraging inquisitive minds. And it is a lot more effort to encourage inquisitive minds and say, "Here is a body of knowledge. Please, go digest." But this certainly could be done.

The raw material is sitting there in every school in the country, and it is, it seems to me, up to policymakers to provide sufficient motivation—carrots and sticks—to bring out all the scientific talent.

[The article from Parade Magazine referred to follows:]

America's getting an F in science and math. So what? So plenty.

Why We Need To Understand Science



Ignorance of science threatens our economic well-being, national security and the democratic process. We must do better.

Carl Sagan

AS I GOT OFF THE plane, he was waiting for me, holding up a sign with my name on it. I was on my way to a conference of scientists and TV broadcasters, and the organizers had kindly sent a driver.

"Do you mind if I ask you a question?" he said as we waited for my bag. "Isn't it confusing to have the same name as that science guy?"

It took me a moment to understand. Was he pulling my leg? "I am that science guy," I said. He smiled. "Sorry. That's my problem. I thought it was yours too." He put out his hand. "My name is William F. Buckley." (Well, his name wasn't *exactly* William F. Buckley—but he did have the name of a constant TV interviewer, for which he doubtless took a lot of good-natured ribbing.)

As we settled into the car for the long drive, he told me he was glad I was "that science guy"—he had so many questions to ask about science. Would I mind? And so we got to talking. But not about science. He wanted to discuss UFOs, "channeling" (a way to hear what's on the minds of dead people—not much it turns out), crystals, astrology. He introduced each subject with real enthusiasm, and each time I had to disappoint him. "The evidence is crummy," I kept saying. "There's a much simpler explanation." As we drove on through the rain, I could see him getting glummer. I was attacking not just pseudoscience but also a facet of his inner life.

And yet there is so much in real science that's equally exciting, more mysterious, a greater intellectual challenge—as well as being a lot closer to the truth. Did he know about the molecular building blocks of life sitting out there in the cold, immense gas between the stars? Had he heard of the footprints of our ancestors found in 4-million-year-old volcanic ash? What about the raising of the Himalayas when India went crashing into Asia? Or how viruses subvert cells, or the radio search for extraterrestrial intelligence or the ancient civilization of Ebla? Mr. "Buckley"—well-spoken, intelligent, curious—had heard virtually nothing of modern science. He *wanted* to know about science. It's just that all the science got filtered out before it reached him. What the society permitted to trickle through was mainly pretense and confusion. And it had never taught him how to distinguish real science from the cheap imitation.

All over America there are smart, even gifted, people who have a built-in passion for science. But that passion is unrequited. A recent survey suggests that 94% of Americans are "scientifically illiterate."

A prescription for disaster. We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology. This is a clear prescription for disaster. It's dangerous and stupid for us to remain ignorant about global warming, sdi, or ozone depletion, toxic and radioactive wastes, acid rain. Jobs and wages depend on science and technology. If the United States can't manufacture, at high quality and low price, products people want to buy, then industries will drift out of the United States and transfer a little prosperity to another part of the world. Because of the low birthrate in the '60s and '70s, the National Science Foundation projects a shortage of nearly a million professional scientists and engineers by 2010. Where will they come from? What about fusion, supercomputers, abortion, massive reductions in strategic weapons, addiction, high-resolution TV, airline and airport safety, food additives, animal rights, superconductivity, Midgetman vs. rail-garrison MX missiles, going to Mars, finding cures for AIDS and cancer? How can we decide national policy if we don't understand the underlying issues?

I know that science and technology are not just cornucopias pouring goodies out into the world. Scientists not only conceived nuclear weapons, they also took political leaders by the lapels and urged that their nation—whichever it happened to be—had to have one first. Then they arranged to manufacture 50,000 of them. Our technology has produced doublemade CFCs, Agent Orange, nerve gas and industries so powerful they can make the climate of the planet. There's a reason people are nervous about science and technology.

And so the image of the mad scientist haunts our world—from Dr. Faust to Dr. Frankenstein to Dr. Strangelove to the white-coated loonies of Saturday morning children's TV. All this doesn't inspire budding scientists. But there's no going back. We can't just conclude that science puts too much power into the hands of morally feeble technologists or corrupt, power-crazed politicians and decide to get rid of it. Advances in medicine and agriculture have saved more lives than have been lost in all the wars in history. Advances in transportation, communication and entertainment have transformed the world. The sword of science is double-edged. Rather, its awesome power forces on all of us, including politicians, a new responsibility—more attention to the long-term consequences of technology, a global and transgenerational perspective, an incentive to avoid easy appeals to nationalism and chauvinism. Mistakes are becoming too expensive.

Science is much more than a body of knowledge. It is a way of thinking. This is central to its success. Science invites us to let the facts in, even when they don't conform to our preconceptions. It counsels us to carry alternative hypotheses in our heads and see which best match the facts. It urges on us a fine balance between no-holds-barred openness to new ideas, however heretical, and the most rigorous skeptical scrutiny of everything—new ideas *and* established wisdom. We need wide appreciation of this kind of thinking. It works. It's an essential tool for a democracy in an age of change. Our task is not just to train more scientists but also to deepen public understanding of science.

How bad is it? Very bad. "It's Offi-

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BY CARL SAGAN

SCIENCE/*continued*

cial," reads one newspaper headline: "We Stink in Science." Less than half of all Americans know that the Earth moves around the Sun and takes a year to do it—a fact established a few centuries ago. In tests of average 17-year-olds in many world regions, the U.S. ranked dead last in algebra. On identical tests, the U.S. kids averaged 43% and their Japanese counterparts 78%. In my book, 78% is pretty good—it corresponds to a C+, or maybe even a B−; 43% is an F. In a chemistry test, students in only two of 13 nations did worse than the U.S. Compared to us, Britain, Singapore and Hong Kong were so high they were almost off-scale, and 25% of Canadian 18-year-olds knew just as much chemistry as a select 1% of American high school seniors (in their second chemistry course, and most of them in "advanced" programs). The best of 20 fifth-grade classrooms in Minneapolis was outpaced by every one of 20 classrooms in Sendai, Japan, and 19 out of 20 in Taipei, Taiwan. South Korean students were far ahead of American students in all aspects of mathematics and science, and 13-year-olds in British Columbia (in Western Canada) outpaced their U.S. counterparts across the boards (in some areas they did better than the Koreans). Of the U.S. kids, 22% say they dislike school; only 8% of the Koreans do. Yet two-thirds of the Americans, but only a quarter of the Koreans, say they are "good at mathematics."

Why we're flunking. How do British Columbia, Japan, Britain and Korea manage so much better than we do?

During the Great Depression, teachers enjoyed job security, good salaries, respectability. Teaching was an admired profession, partly because learning was widely recognized as the road out of

poverty. Little of that is true today. And so science (and other) teaching is too often incompetently or uninspiringly done, its practitioners, astonishingly, having little or no training in their subjects—sometimes themselves unable to distinguish science from pseudoscience. Those who do have the training often get higher-paying jobs elsewhere.

We need more money for teachers' training and salaries, and for laboratories—so kids will get hands-on experience rather than just reading what's in the book. But all across America, school-bond issues on the ballot are regularly defeated. U.S. parents are much more satisfied with what their children are learning in science and math than are, say, Japanese and Taiwanese parents—whose children are doing so much better. No one suggests that property taxes be used to provide for the military budget, or for agriculture, or for cleaning up toxic wastes. Why just education? Why not support it from general taxes on the local and state levels? What about a special education tax for those industries with special needs for technically trained workers?

America's kids don't do enough schoolwork. The average high school student spends 3.5 hours a week on homework. The total time devoted to studies, in and out of the classroom, is about 20 hours a week. Japanese *fifth*-graders average 33 hours a week.

But most American kids aren't stupid. Part of the reason they don't study hard is that they've received few tangible benefits when they do. Competency (that is, actually knowing the stuff) in verbal skills, mathematics and science these days doesn't increase earnings for average young men in their first eight years out of high school—many of whom take service rather than industrial jobs.

In the productive sectors of the economy, though, the story is different. There are furniture factories, for example, in danger of going out of business—not because there are no customers but because few entry-level workers can do simple arithmetic. A major electronics company reports that 80% of its job applicants can't pass a *fifth*-grade math test—and that's an American, not a Korean, fifth-grade test. The United States already is losing some $25 billion a year (mainly in lost productivity and the cost of remedial education) because workers, to too great a degree, can't read, write, count or think. Parents should know that their children's livelihoods may depend on how much math and science they know. Now, while the kids are in school, is the time for them to learn. Parents ought encourage their schools to offer—and their kids to take—comprehensible, well-taught advanced science courses. They might also limit the amount of mind-numbing TV their children watch.

What we can do. Those in America with the most favorable view of science tend to be young, well-to-do, college-educated white males. But three-quarters of new American workers between now and 2001 will be women, nonwhites and immigrants. Discriminating against them isn't only unjust, it's also self-defeating. It deprives the American economy of desperately needed skilled workers.

Black and Hispanic students are doing better in standardized science tests now than in the late 1960's, but they're the only ones who are. The average math gap between white and black U.S. high school graduates is still huge—two to three grade levels, but the gap between white U.S. high school graduates and those in, say, Japan, Canada, Great Britain or Finland is more than *twice* as big. If you're poorly motivated and poorly educated, you won't know much—no mystery here. Suburban blacks with college-educated parents do just as well in college as suburban whites with college-educated parents. Enrolling a poor child in a Head Start program doubles his or her chances to be employed later in life; one who completes an Upward Bound program is four times as likely to get a college education. If we're serious, we know what to do.

What about college and university? There are obvious steps similar to what should be done in high schools: salaries for teachers that approach what they could get in industry; more scholarships, fellowships and laboratory equipment; laboratory science courses required of everyone to graduate; and special attention paid to those traditionally steered away from science. We should also provide the financial and moral encouragement for academic scientists to spend more time on public education—lectures, newspaper and magazine articles, TV appearances. This requires scientists to make themselves understandable and fun to listen to. To me, it seems strange that some scientists, who depend on public funding for their research, are reluctant to explain to the public what it is that they do. Fortunately, the number of scientists willing to speak to the public—and capably—has been increasing each year. But there are not yet nearly enough.

Virtually every newspaper in America has a daily astrology column. How many have a daily science column? When I was growing up, my father would bring home a daily paper and comment (often with great gusto) the baseball box scores. There they were, in one dry as dust, with obscure abbreviations (W, SS, SO, W-L, AB, RBI), but they spoke to him. Newspapers everywhere printed them. I figured maybe they weren't too hard for me. Eventually I too got caught up in the world of baseball statistics. (I know it helped me in learning decimals, and I still cringe a little when I hear that someone is "batting a thousand." But 1.000 is not 1,000. The lucky player is batting one.)

Or take a look at the financial pages. Any introductory material? Explanatory footnotes? Definitions of abbreviations? Nope. It's sink or swim. Look at those acres of statistics! Yet people voluntarily read the stuff. It's not beyond their ability. It's only a matter of motivation. Why can't we do the same with math, science and technology?

By far the most effective means of *ruining* interest in science is television. There's lots of pseudoscience on TV, a fair amount of medicine and technology, but hardly any science—especially on the three big commercial networks, whose executives think science programming means ratings declines and lost profits, and nothing else matters. Why in all America is there no TV drama that has as its hero someone devoted to figuring out how the Universe works?

Starting projects in science and technology attract and inspire youngsters. The number of science Ph.D.'s peaked around the time of the Apollo program and declined thereafter. This is an important potential side-effect of such projects as sending humans to Mars, or the Superconducting Supercollider to explore the fine structure of matter, or the program to map all human genes.

Every now and then, I'm lucky enough to teach a class in kindergarten or the first grade. Many of these children are curious, unintellectually vigorous, ask provocative and insightful questions and exhibit great enthusiasm for science. When I talk to high school students, I find something different. They memorize "facts." But, by and large, the joy of discovery, the life behind those facts, has gone out of them. They're worried about asking "dumb" questions, they're willing to accept inadequate answers, they don't pose follow-up questions, the room is awash with sidelong glances

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SCIENCE/*continued*

to judge, second-by-second, the approval of their peers. Something has happened between first and 12th grade, and it's not just puberty. I'd guess that it's partly peer pressure *not* to excel (except in sports); partly that the society teaches short-term gratification; partly the impression that science or math won't buy you a sports car; partly that so little is expected of students; and partly that there are so few role models for intelligent discussion of science and technology or for learning for its own sake.

But there's something else: Many adults are put off when youngsters pose scientific questions. Children ask why the Sun is yellow, or what a dream is, or how deep you can dig a hole, or when is the world's birthday or why we have toes. Too many teachers and parents answer with irritation or ridicule, or quickly move on to something else. Why adults should pretend to omniscience before a 5-year-old, I can't for the life of me understand. What's wrong with admitting that you don't know? Children soon recognize that somehow this kind of question annoys many adults. A few more experiences like this, and another child has been lost to science.

There are many better responses. If we have an idea of the answer, we could try to explain. If we don't, we could go to the encyclopedia or the library. Or we might say to the child: "I don't know the answer. Maybe no one knows. Maybe when you grow up, you'll be the first to find out."

But mere encouragement isn't enough. We must also give children the tools to winnow the wheat from the chaff. I'm haunted by the vision of a generation of Americans unable to distinguish reality from fantasy, hopefully clutching their crystals for comfort, unequipped even to frame the right questions or to recognize the answers. I want us to rescue Mr. "Buckley" and the millions like him. I also want us to stop turning out leaden, incurious, unimaginative high school seniors. I think America needs, and deserves, a citizenry with minds wide awake and a basic understanding of how the world works.

Public understanding of science is more central to our national security than half a dozen strategic weapons systems. The submediocre performance of American youngsters in science and math, and the widespread adult ignorance and apathy about science and math, should sound an urgent alarm. ■

Carl Sagan teaches and does research at Cornell University. His Emmy and Peabody Award-winning TV science series COSMOS has been seen in more than 60 countries by 400 million people. Videocassettes of all 13 episodes will be available in stores later this year from Turner Home Entertainment. The accompanying book, "Cosmos," is the best-selling science book ever published in the English language.

The CHAIRMAN. Thank you very much. As always, it is fascinating to hear your comments on a range of different issues. We appreciate your presence here.

I am going to ask our next group of witnesses to come up together: Dr. Shirley Malcom, Head, Directorate of Education and Human Resources Program, American Association for the Advancement of Science; Dr. Irwin Shapiro, Director of the Harvard-Smithsonian Center for Astrophysics, Harvard University; Dr. Leon Lederman, Nobel Laureate and Director Emeritus of Fermilab, in Batavia, IL; and Ms. Lourdes Monteagudo, Deputy Mayor for Education, City of Chicago.

Dr. Malcom, we'll start with you.

STATEMENTS OF DR. SHIRLEY M. MALCOM, HEAD, DIRECTORATE OF EDUCATION AND HUMAN RESOURCES PROGRAMS, AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, WASHINGTON, DC; DR. IRWIN SHAPIRO, DIRECTOR, HARVARD-SMITHSONIAN CENTER FOR ASTROPHYSICS, HARVARD UNIVERSITY, CAMBRIDGE, MA; DR. LEON M. LEDERMAN, NOBEL LAUREATE, DIRECTOR EMERITUS, FERMILAB, BATAVIA, IL; AND LOURDES MONTEAGUDO, DEPUTY MAYOR FOR EDUCATION, CITY OF CHICAGO, CHICAGO, IL

Dr. MALCOM. Thank you very much.

I appreciate the opportunity to come before this committee once again. I will ask that my prepared statement be entered into the record, and then I will simply make a few brief remarks.

I think that anyone who looks at the current data cannot help but realize that we are going to need more scientists and engineers and more people who are scientifically and technologically literate than I can see coming down the pipeline.

Circumstances really mitigate against attaining these goals. First of all, there is a declining interest in science majors by our young people who are entering as freshman in college. Second, the size of that pool of young people is shrinking. Third, we can expect the retirement of some of our most experienced scientists and engineers, who came in after Sputnik to help us in the space race.

Next, there declining interest in graduate education by U.S. citizens. There is a growing minority proportion of this shrinking talent pool. Women are an increasing part of the work force and are 50 percent of the talent pool that is available for science and engineering.

There is poor performance by all students in science and mathematics, but even poorer performance by our minority students in tests of performance in science and mathematics.

The bottom line is that collectively, groups with a weak tradition for science and engineering are around two-thirds of the talent pool. That is the bottom line.

What needs to be done? I think we are going to have to face up to the fact that what we are trying to fix is an extremely complex system, and we're going to have to face up to that complexity and face up to the fact that it is a system which will need a systems approach to fixing the problems.

We are going to have to go for bold reform. We are going to have to emphasize the need for approaches and programs that add up to a comprehensive systemwide strategy rather than tinkering around the edges.

Next, everybody is going to have to get onboard, all of the stakeholders. We are going to have to go for Federal, State and local partnerships. We are going to have to emphasize the need to bring everyone along, not just the talented few, but everyone.

We are going to have to set national goals—what do we want students to know and to be able to do—because that is going to have to guide what it is we do within our schools.

We are going to have to stop putting it off. The situation is critical, and we are going to have to move on it and move on it in a way which gives us something coherent and systemwide when we finish.

We are going to have to focus in two different areas. One is what do we do until the system is reformed, and what do we do in the process of that reformation.

I think that we have to think about some things that we need to stop doing as well. I think that we have to stop saying that because the Federal investment is so small compared to the size of the State and local investment that this is an excuse for backing off of the issue of resources.

There is a way to leverage the 6 to 7 percent that is already here, that is already the Federal investment. In our programs, we have instances of where $5,000 investments have been leveraged to $500,000 programs. It can be done if we understand the system and if we know where to apply the pressure.

I think the other thing that we need to stop doing is top looking for magic bullets. We hear words thrown around that don't necessarily have meaning—words such as "choice", which we know only works if you perceive that you have one and know how to exercise it.

It is complex; it is going to be hard, and it is going to take a long time to undertake systemwide reform. But we will be able to see the progress along the way.

There are some candid ideas about how to do good and how especially to support the expansion of the pipeline for women and for minorities. First, support the good things that are needed for reform or needed until we achieve reform. We already know how to do a lot of things. We have hundreds, even thousands, of intervention programs that are out there. These things need support.

We have to support the efforts to professionalize teaching, those that are coming from the community itself. We have to support the efforts for early childhood education. Support the good things that are out there.

The second issue is that we have to rethinking some of what we are doing. We cannot continue, for example, to retrain teachers one at a time. We are going to have to realize how organizations change and think about how we can change them and retrain them a school at a time, or a district at a time, and build ways so that they can help each other in this retraining process.

We are going to have to focus more resources where the problems are. The problems are particularly severe at the elementary and middle-school levels.

We have to focus the resources on the groups that we are trying to improve. I support the need to improve science and mathematics education for everyone, but I particularly support the need to raise the floor for minority students in particular in our inner cities who do not even have the access to a mediocre education.

Restructuring. Restructuring is a process, but not an end to itself. What are the content goals that we want achieved in restructuring? In discussions to date on restructuring, it is unfortunate but true that the emphasis has been on what everyone will get out of the restructuring except the children. We do not raise performance levels by focusing on floors that are already too low.

Yuri Treisman and Jaime Escalante I think have taught us that you excel by raising the standards, that you excel by having high achievement expectations. We have to recognize the interconnectedness of the pipeline. There really is a connection between the status of women on the faculties of our colleges and universities and what happens when a young woman comes in at the freshman level and decides to continue or not to continue as a science major. There really is a connection. The marginal status of women faculty sends a message to that undergraduate that maybe she doesn't want a part of this.

We are losing women in particular at the upper levels. We are failing to retain extremely able people to science.

At the undergraduate level, some particular areas that are candidates for reform are the entry and survey-level courses; how people meet the disciplines. There is a mentality that relates to weeding people out rather than to cultivate and nurture them, and a value system which unfortunately does not reward teaching.

But the greatest challenge is filling the pipeline at the precollege level. We are going to have to look at the need for all of the elements of the system to work together. For teachers, this would mean providing experiences that increase their subject knowledge and teaching strategies with proven effectiveness and improving their ability to meet the needs of the diverse student populations they will find in their classrooms and raise the expectations for all students. For content, this means offering more rigorous and enriching materials that promote high-ordered skills and contextually-based learning over drill and memorization; content that explicitly recognizes the participation of diverse populations in science and technology and that respects that difference.

Contextually, it means finding and using examples and experiences that are appropriate for, recognizable by and drawn from the culture and experiences that the children bring.

It means restructuring schools to better serve the learning needs of students—all students—and realistic budgeting for expenses associated with providing hands-on science instruction.

We have to connect, as David Hamburg, President of Carnegie Corporation, often says, the science-rich and the science-poor parts of the community. We have programs at AAAS that work to bring science into black churches, into Saturday experiences, that work to use the youth-serving groups and community organizations that

are already in those communities as the conduits for hands-on science and for the values that emphasize that science is important and science is necessary to everyone's life.

We know what to do. Now we need the will, the leadership and the resources to do this.

Thank you.

The CHAIRMAN. Very good. Thank you.

[The prepared statement of Dr. Malcom follows:]

PREPARED STATEMENT OF DR. SHIRLEY M. MALCOM

Thank you for the opportunity to present testimony before the Senate Committee on Labor and Human Resources. I am Shirley M. Malcom, Head of the Directorate for Education and Human Resources Programs of the American Association for the Advancement of Science (AAAS).

The 19 September 1988 issue of Business Week carried a cover story entitled "Human Capital: The Decline of America's Work Force." It went on to state:

> "The nation's ability to compete is threatened by inadequate investment in our most important resource: people. Put simply, too many workers lack the skills to perform more demanding jobs. And as the economy comes to depend more and more on women and minorities, we face a massive job of education and training-starting before kindergarten. Can we afford it? We have no choice."

Several points in this statement guide my testimony today:

- The changing nature of work;
- The need for scientists and engineers;
- The challenges of the changing demographics; and
- Women and minorities: filling the pipeline.

THE CHANGING NATURE OF WORK

According to the Hudson Institute (Workforce 2000), we are facing a mismatch between jobs and skills. Most of the new jobs

will require higher levels of literacy (verbal and writing skills). They will most likely also require stronger mathematical skills and the ability to use technology. But too many of the nation's new workers will lack these skill levels, leading to a condition, as Kay Whitmore of Kodak has described it, of "having jobs without people at the same time that there are people without jobs." At a time when growth in jobs (coupled with a shrinking pool of young people) presents a unique opportunity to catch up economically, many of the "new workers," especially women and minorities, will be unprepared to take advantage of these circumstances. Not only will the new jobs be different, but the old jobs are changing as well. Technology is transforming the nature of work in most jobs. But the changes in the expected work requirements have not influenced the way we educate our future workers. In addition, our present workforce has immense retraining needs. While the latter topic could occupy (and has occupied) separate hearings, I will, as requested, focus on the problem of preparing our future workers.

THE NEED FOR SCIENTISTS AND ENGINEERS

Economists have estimated that about one-third of the gain in gross national product between 1948 and 1982 was caused by the increase in the education level of the U.S. workforce and about half the growth was the result of technological innovation and increased know-how. The pivotal position of scientists and engineers as generators of knowledge cannot be denied. Although we are only about 4 percent of American workers, we have

specialized knowledge and skills vital to the Nation. According to the Office of Technology Assessment report, Educating Scientists and Engineers: Grade School to Grad School, "They [scientists an engineers] widen human understanding by doing basic research and teaching, they develop and apply new technologies of every kind, and they keep the national manufacturing base running smoothly." The report notes that while it is impossible to project accurately the demand for scientists and engineers, historically the demand has been rising.

But a confluence of factors raises serious concern as to whether a steady flow of scientists and engineers can be maintained.

- The percentage of 18 to 24 year olds in the U.S. population will decline by roughly 20 percent between 1990 and 2000.
- The minority proportion of the 18-24 year old population is increasing. Blacks and Hispanics are now 25 percent of school children; by 2000, they will be 47 percent.
- The proportion of students choosing to major in these fields is decreasing. According to the Cooperative Institutional Research Program, between 1966 and 1988 the proportion of college freshman planning to major in the sciences and mathematics fell by half, from 11.5 to 5.8 percent. The greatest portion of the decline occurred in mathematics (from 4.6 to 0.6 percent) and in the physical sciences (from 3.3 to 1.5 percent).
- Many of our most experienced scientists and engineers who came in the post-Sputnik workforce will be retiring in the 1990's. Within the next six years, it is estimated that 25 percent of engineering faculty will reach age 65, when many are likely to retire. Their departure will come at a time when many departments already faced faculty shortages.

- A shrinking proportion of American students are choosing to continue in graduate education in science and engineering to the PhD. In 1988 of 749 doctorates awarded in mathematics by U.S. universities, only 341 were received by U.S. citizens.

- While women are over half of all college students and minorities (American Indians, Blacks and Hispanics) are a growing fraction of a shrinking pool of college age young people, members of these groups are seriously underrepresented in science and engineering fields. In 1988 American Indians, Blacks and Hispanics received only 6 of the 341 doctorates in mathematics and only 4 of the 514 PhDs in computer science awarded to U.S. citizens. American women earned 6.5 percent of all engineering PhDs awarded in 1987.

THE CHALLENGES OF THE CHANGING DEMOGRAPHICS

The net result of the changing demographics is that there is a lower population in the pipeline of groups that traditionally enter fields of science and engineering. This argues for including underrepresented groups prominently in any strategy to ensure a steady flow of scientific and technical talent for the United States. The Congress took an important first step to include issues related to women and minorities in policy and program discussions on human resources for science and engineering in 1980. The passage of the Equal Opportunity in Science and Engineering legislation had profound effects on the National Science Foundation. The establishment of the Committee on Equal Opportunity and production of the biennial report, Women and Minorities in Science and Engineering helped build a base of programs and a base of evidence of the looming human resources crisis. As prime sponsor of that legislation, Senator Kennedy, you are to be congratulated for the leadership you demonstrated.

Illustrative of the strong bipartisan support we have had on this issue, Senator Hatch was the driving force behind PL 99-383, Section 8, which established the Task Force on Women, Minorities and the Handicapped in Science and Technology. You, too, are to be congratulated on the leadership you demonstrated in recognizing the need for a coordinated federal-wide strategy to deal with one of the most critical science policy issues of our time: who will do science and engineering in the 1990's and beyond.

Women, minorities and people with disabilities must be brought into science and engineering. The shrinking pool of talent for science and engineering means that we must draw a larger proportion of these underrepresented groups into the pipeline.

Further, educational strategies that emphasize weeding students out must be replaced with those that emphasize nurturing and cultivating. We have depended on natural interest and self-selection by highly talented students to replenish the ranks of scientists and engineers. Such a hands-off approach is dangerous when two-thirds of the available talent have a weak tradition and little active encouragement to pursue these careers. That is, science careers have weak pull and little push for most of those who might enter. In addition, the filtering process begins very early in the educational system. Since education before college is largely the purview of states and local government, only a consensus on the need for national goals can ensure that students

emerge from the precollege years with all options intact, including the options for science and engineering. The change in demographics is encouraging a national dialogue on the need for quality education for all and on the need to decide what the quality education looks like. Only then can we begin to talk about how it might be achieved.

The acknowledged federal role in science and mathematics education and in promoting equity for minority, poor, disadvantaged, disabled and female students merges with this concern for filling the pipeline. It also argues for partnerships with states and localities in achieving this end.

WOMEN AND MINORITIES: FILLING THE PIPELINE

If we are to broaden the diversity and increase the number of people choosing science and engineering careers we must realize that a "total pipeline approach" is needed. We must realize that the production of a top-notch scientist depends, as sociologist of science Robert Merton has suggested, on a process of "cumulative advantage" -- quality education at all levels, mentors, support, and encouragement.

Perhaps here one should introduce the notion of "cumulative disadvantage" to describe the nature of the educational experiences which we provide to children living in the ghettos and barrios of our inner cities. It should be surprising that any scientist, engineer or mathematician emerges at all from among underrepresented groups in a society where we send a message that girls don't do math or science, that ability is less

likely to be present among Blacks, that speaking another language implies deficiency, or where the focus is on one's disability rather than on one's ability.

Although young women have increased the number of mathematics and science courses they take in high school, they are still underrepresented in the highest level courses in these fields. For the most part gender differences in mathematical performance on the National Assessment of Educational Progress are minimal at ages 9 and 13 and only slightly larger at age 17. In science the average performance of males and females declined from 1970 to the mid 1970's. Some recovery in performance occurred during the 1980's. But on the whole the performance gap between males and females increased over that time for 9 and 13 year olds. In fact, the gap between 13 year old males and females appears to have more than doubled across the five assessment," according to The Science Report Card, the report of the 1986 National Assessment.

Even young women who emerge from the precollege experience with science, math or engineering interest, having taken "the right courses," are likely to face new hurdles in their undergraduate years.

The pipeline for science and engineering is intrinsically leaky for all students during the undergraduate years. The CIRP studies of freshman preferences indicate that "a large proportion of aspiring science majors ultimately abandon the sciences for other fields." According to Kenneth C. Green, "the sciences have

the highest defection rates of any undergraduate major... and the lowest rates of recruitment from other fields."

In trying to convert these able bachelor's degree recipients into graduate school enrollers, and ultimately, into doctoral degree recipients we find yet another set of problems:

- Women students often find themselves in isolation within their departments;
- They are less likely to receive financial support through research assistantships; and
- They may lack the informal networks.

Few women faculty are present to serve as role models. Too often the marginal position of women in science and engineering is underscored by the women who serve in adjunct, lecturer and associate positions on the periphery and off-tenure track.

These women, who have so many gifts, may perceive that they must make a choice between family and career since the kind of institutional social policy which might make it possible to do both may be absent.

If the prospects for women in science and engineering are poor, the prospects for minorities are dismal. Using any indicator of educational attainment, American Indians, Blacks and Hispanics do not achieve in science and mathematics at levels necessary for literacy and numeracy. They are not only underrepresented in careers in science and engineering, but also in occupations which require quantitative and technical skills. These problems of underparticipation originate in the educational preparation of American Indian, Black and Hispanic youth -- in

schools, in communities and in the homes. So, too, must the solutions reside in these places.

For underrepresented minorities, barriers to the coursework which give access to scientific and technical literacy and careers begin and are particularly severe at the pre-college level. A brief examination of the indicators of educational status point out a number of problems.

ACHIEVEMENT AND EXPERIENCES IN MATHEMATICS AND SCIENCE

Although there has been improvement in the scores of Black and Hispanic youth over earlier tests, their scores fall below the national average in mathematics and science on the 1986 National Assessment of Education Progress. In like manner, college bound minority youth score below the national average on college entrance tests. If we look at the background which students bring to the testing setting we find that Black and Hispanic students have had less rich experiences with the things and ideas of science. Fewer Black and Hispanic third graders report that they have used a yardstick, a scale to weigh, a magnifying glass, a microscope or telescope than their white counterparts. While the gap closes somewhat for seventh graders, by 11th grade the gaps reappear, especially for experiences one would likely have either out-of-school or in courses in the physical sciences.

COURSETAKING

When 17 year old participants in the 1986 National

Assessment of Education Progress (NAEP) were asked the highest level mathematics course they have taken, 34 percent of whites, and 49 percent of Black and Hispanics indicated Algebra I or pre-Algebra. Data from the High School and Beyond study support these findings. Minority students do not tend to take the higher level mathematics courses in high school such as Algebra II, geometry, and trigonometry which they need to pursue education and subsequent employment in science, engineering, computing, business, health/medicine, architecture and many associate level technical fields. More rigorous requirements which are being instituted for teachers in elementary and middle schools would preclude entry into teaching -- in years past, one of the "majors of choice" for mathematics avoiders.

The High School and Beyond survey reveals low levels of science coursetaking for all students, especially underrepresented minorities and especially in the physical sciences.

OPPORTUNITY TO LEARN

Underrepresented minority students are less likely to be in the academic track in high school, less likely to participate in programs for the gifted and talented and are more likely to be in remedial programs. While data are available on programs and courses at the high school level, there is much evidence that homogeneous grouping as early as primary grades and especially in mathematics and reading is prevalent; such groupings can lead directly to later tracking. Since less input is being provided,

students are denied the opportunity for exposure to more rigorous content and concepts which are usually precursors to more advanced work in high school. Evidence is emerging from studies by Jeannie Oakes of The Rand Corporation that schools which minority students attend are more likely to have less able teachers and less rich course offerings.

WHAT CAN BE DONE?

While the experience of girls and minorities in science and mathematics is different, there are significant parallels in the barriers which they face. In both cases we find that girls and minorities show considerable success in out-of-school programs which stress hands-on involvement with science, use of manipulatives in mathematics, cooperative learning and peer tutoring. Where there are high expectations, where an appropriate context for learning is provided and where parents are involved in supporting science and mathematics learning, both groups of students achieve in science and mathematics.

Some of the differences in relative socioeconomic status, the extent of poverty, social disruption and other aspects of the larger social environment (substance abuse, family status, incidence of teen pregnancy, health status) which minorities disproportionately face affects the experiences which minority youth bring to formal and informal learning settings. Any intervention must be undertaken with full cognizance of these larger issues and of the need to deal with the whole child in an appropriate cultural context.

Providing quality education to minorities is important in and of itself, but ultimately in addressing these other societal issues. What does this mean for programming? At the least it means that activities aimed at minorities may have to be of longer duration, sustained over time and more comprehensive in nature. For example, communications skills may need to receive attention along with math and science; or programs may need to be run not only in the summer, but also with academic year follow-up.

We know how to run out-of-school programs that take place after school (such as homework centers, tutoring and enrichment programs), on weekends (such as Saturday Academies), and in summer (such as camps, research apprenticeships). We have evidence to support the fact that these interventions are effective in exposing minority youth to rigorous academic programs, to careers that use math and science, to peers who aspire to academic success, to role models who have overcome circumstances similar to theirs in order to be successful. These projects have focused on enhancing skills and providing enrichment in science, mathematics and communications; they focus on career planning, study and test taking skills. They aim to build a community of learners. If we are to increase minority student success in science and mathematics at the pre-college level, we must increase the amount and quality of contact which students have with these subjects, both in and out of school.

The greatest challenge which we face may be fixing the

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system of school science and mathematics so that it appropriately responds to the needs of all children. For in order to do this we must affect the entire learning system: teachers, administrators, role models in the community, subject content and context, teaching methods, schools and parents.

- For teachers this would mean providing experiences that will increase their subject knowledge, and teaching strategies with proven effectiveness; improving their ability to meet the needs of diverse student populations and raise their expectations for all students.

- For content this means offering more rigorous and enriching material that promotes higher order skills and contextually-based learning over drill and memorization; content that explicitly recognizes the participation of diverse populations in science and technology and that respects difference.

- Contextually it means finding and using examples and experiences that are appropriate for, recognizable by and drawn from the cultures of the children being taught.

- It means restructuring schools to better serve the learning needs of students, such as by allowing for flexibility in scheduling (blocks of time long enough to undertake lab work), and realistic budgeting for expenses associated with providing hands-on science instruction.

Perhaps the most promising intervention strategy would be to bring all parts of a child's life into "sync" -- when school, community and family can become mutually reinforcing learning systems. These young people must be provided opportunities to encounter science, mathematics and technology throughout their lives: in museums, zoos and other places of science; in employment settings such as hospitals, water treatment plants; in their communities; and in their homes.

CONCLUSION

We have been slow to recognize the threat that is posed by failing to develop a dwindling talent pool -- a talent pool which is very different from that which we drew upon in the post-Sputnik years. American Indians, Blacks and Hispanics can and must be a part of the solution to America's need for scientific and technological talent.

Tinkering around the edges will not help us maintain a world-class scientific and technological enterprise. We must rethink and restructure the system for the production of scientists and engineers from pre-K through graduate education. What needs to be done? Two tasks are primary:

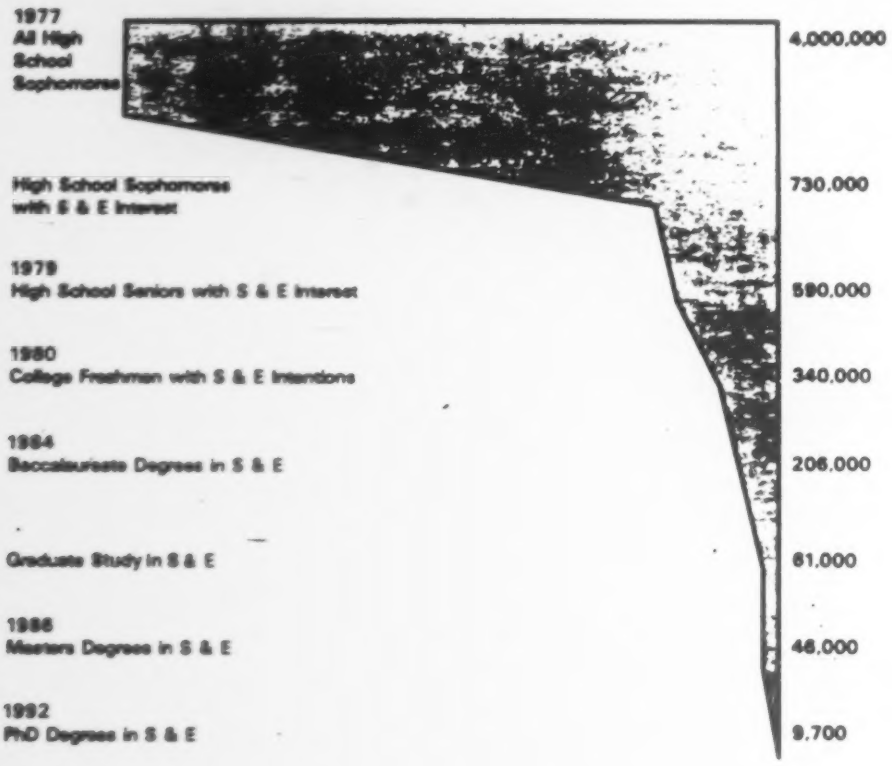
(1) The agencies and departments of the federal government must find targets of opportunity around a single coherent plan. The final report of the Federal Wide Task Force on Women Minorities and the Handicapped in Science and Technology, on which I serve, can be a focal point for discussions of cooperation and collaboration which need to take place. Gaps in programming need to be identified and filled by the appropriate agency or department.

(2) Congress must support these efforts. We would encourage the Congress to look at the need for legislation to support improved science, mathematics and technology education in a manner similar to the way it approached the Omnibus Trade Bill. The way in which legislative responsibility and oversight for education is currently divided does not easily

allow for development of a coherent legislative strategy. We call upon the leadership of both Houses of Congress and the very competent leadership in this Committee to assemble a Congressional summit on science, mathematics and engineering education, to extend the dialogue and to model for the agencies and states the way to develop a coherent policy. Everyone has a part to play in configuring and implementing a solution. The AAAS stands ready to assist in whatever way we possibly can.

APPENDIX

Science & Engineering Pipeline, from High School through Ph.D. Degree



Analysis of the 4 million students in the 10th grade in 1977 shows the pattern of attrition as they move through the educational pipeline. Approximately 9,700 or 0.24 percent are expected to attain the Ph.D. in science and engineering.

Source: National Science Foundation.

Biographical Sketch

for

Shirley M. Malcom

Shirley Malcom is currently Head of the Directorate for Education and Human Resources Programs of the American Association for the Advancement of Science (AAAS), a new position to which she was named in July 1989. The Directorate includes all AAAS programs in education, activities for underrepresented groups and public understanding of science and technology. Dr. Malcom was previously head of the Office of Opportunities in Science, a position she held for almost 10 years. The Office is concerned with increasing the participation of minorities, women, and disabled persons in science and engineering careers and with the impact of science and technology on these groups. Between 1977 and 1979, Dr. Malcom served as Program Officer in the Science Education Directorate of the National Science Foundation (NSF). Prior to this, she held the rank of Assistant Professor of Biology, University of North Carolina, Wilmington.

Dr. Malcom received her doctorate in ecology from the Pennsylvania State University; master's degree in zoology from the University of California, Los Angeles,; and bachelor's degree with distinction in zoology from the University of Washington.

Dr. Malcom is a member of the Advisory Council of the Carnegie Forum on Education and the Economy and served on the Carnegie Forum's Task Force on Teaching as a Profession. She serves on the Education Advisory Council of the Carnegie Corporation of New York and as a member of the board of the National Center on Education and the Economy. From 1984-1986 she was Chair of the National Science Foundation Committee on Equal Opportunities in Science and Technology. In 1987 she was appointed to the Federal Wide Task Force on Women, Minorities and the Handicapped in Science and Technology. Dr. Malcom has served on numerous boards, including the education advisory committee of the National Urban League. She has been nationally recognized for her efforts, and those of the Office, to improve the education of minority young people by involving community organizations and parents in education reform. In 1987, Dr. Malcom was recognized as one of five honored by the National Council of Negro Women (NCNW)/Frito-Lay "Salute to Black Women Who Make it Happen".

July 1989

The CHAIRMAN. Dr. Shapiro?

Dr. SHAPIRO. I greatly appreciate the opportunity to talk with this committee, especially on such an important subject.

I would remind everyone of Mark Twain's famous words: "Everybody talks about the weather, but nobody does anything about it." You might ask, well, why does everybody talk about it if you can't do anything about it? What is the point? The point is it is an important problem, and it affects everyone; that is why they talk about it.

Education has this in common with the weather. It is also very important, and it also affects everyone. But it has a basic difference: We can do something about it. And statistics, tests and polls all point the same way: We must do something about it.

What we tried to do is see for ourselves in various ways, just to get a feeling for the dimensions of the problem. One of the things we did was take interviews of recent graduates. In fact, we actually went to the graduation ceremony at one of our most prestigious universities in Massachusetts and interviewed these graduates in caps and gowns. We asked them a seemingly simple question: Why is it warmer in the summer and colder in the winter? Everybody knows it is warmer in the summer and colder in winter. Why?

Well, all these graduates were sure they knew the answer, and in a slightly condescending tone and very articulately, they explained the answer. Virtually all of them were wrong. They said it is warmer in the summer because the earth is closer to the sun in the summer and colder in the winter because the earth is further away. That is not the right answer.

We also had one assistant professor of the history of science who didn't know an elementary concept, who just happened to be interviewed in that same session.

Anyway, it really is sad that the most basic things are really misunderstood. And what is worst of all, many people think they understand, and they don't. That is probably the worst thing of all.

Carl mentioned that he has noticed that in young children, they are all inquisitive, they all ask questions, and as soon as they get to high school—and I might add especially when they get to college—they are afraid to ask a stupid question because they will look stupid in the eyes of their peers. But one-on-one, that instinct, that desire to learn, that inquisitiveness is not dead in us.

I travel a lot. I often sit next to somebody, and I never fail to ask them these simple questions, like why is it warmer in the summer and colder in the winter. I ask it to jewelry salesmen, lawyers, stockbrokers, school teachers, anyone who happens to be sitting next to me—and without exception—and granted, these are relatively small statistics—but without exception, every one of these people did not know the answer but was eager to learn and always by the end of the conversation said to me: "Can you recommend a good book where I can learn about these things?" So the inquisitiveness is still there despite the different occupations that these people are in—but they sure didn't learn much in school.

OK. What can we do about it? Obviously, we want to do something. Well, we couldn't do everything, but we decided to set out on a course of developing some curricular materials to teach fundamental principles of physics and mathematics, using examples

from astronomy because it seems most youngsters are really taken with things in space; it is a very visual science, and all youngsters seem to be interested.

The first thing we had to do, of course, was develop an acronym. So we chose "Project STAR"—Science Teaching through its Astronomical Roots—because astronomy was really the first quantitative science, and that seemed neat. So off we went.

First, we developed a lot of facts. We discovered, for example, that in this whole country, there is not a single high school text in astronomy or space science, and the texts that do exist in physics and mathematics are so densely filled with concepts and have so much jargon in them that it is very difficult, virtually impossible, for the students to figure out what is going on and almost as difficult for the teachers to figure out what is going on.

For example, you might find a device like this, described as one which "will allow pressure-induced vorticity to generate oscillatory sound phenomena" instead of just calling it a "whistle".

It is amazing. If you look through these books, you can eliminate almost all the specialized and intimidating jargon which, when you have mastered anyway, you know nothing. If you know the name of a bird in Latin, you don't know a darned thing about the bird when you just know its name. Concepts are the important thing.

So the approach, we decided, was first of all seeing how many people really misunderstood things when they thought they understood them, that we have to confront these misconceptions early on in our attempt to teach, and that we should attempt to teach only a very few fundamental principles and show how they can be applied in many different contexts. This way you get a feeling for one of the essences of science, that a little goes a very long way; the more fundamental, the longer a way it goes. So we feel it is very important to do that. Also, it helps the teachers because they don't have to learn so much, and they can learn what they have to learn better. So from all angles, this seemed to be a good approach.

We also felt, as has been mentioned by Ms. Malcom just before, and also by Senator Hatfield, that hands-on activities are good ways to learn. People learn better when they do things for themselves. So we decided to develop devices that the students could build themselves, could use themselves, and were cheap enough that they were accessible to virtually everyone.

So here, I have a very complicated device. It is two pieces of wax, with a little aluminum foil in between, all tied together with two rubberbands—nothing very esoteric—but we have an extremely sensitive device for telling whether the light coming in on this side is more or less than the light coming in on this side. Maybe you can see from there, the top of this is brighter than the bottom; just to show you that I'm not tricking you, it works just as well the other way; and I can turn it sideways and move it back and forth, and you can see very precisely whether more light is coming from that side or from the other side.

So what do kids do with a device like this? With a device like this and an ordinary incandescent bulb, and just a slight tough of deus ex machina, students can measure how much light the sun puts out. It is not obvious to you, but with a device like this and a

simple bit of arithmetic, they can calculate how much light comes to the sun, that is, how much leaves the sun.

OK. We also have another simple device—I won't go on ad nauseam, but I will show you a few more—we have here just an ordinary flashlight with a small piece of Scotch tape and little bit of aluminum foil, the Scotch tape holding down what you cannot see from there, but there is a little bit of high-tech optical fiber—total cost, ten cents, for the optical fiber. Now, when we turn on the flashlight, a microwatt of power comes out of the end of that optical fiber. You probably can't see it from there, but you can see it if you were close. With this device, students can go out at night and measure the distance to the nearest stars.

It is really mind-boggling. When you look up at the sky, you have no idea whether the stars are a mile away or a billion miles away or a trillion miles away—but with one scientific principle, which I won't go into in detail here, and this little device, which really is a ten-cent investment for most people, since they normally have the other things at home, they can go out and actually measure the distances to starts to amazing accuracy—not to the hundredth of a percent, but to a factor of two, which is pretty amazing.

We also have developed a telescope more powerful than Galileo's that we can build from paper towel tubes. If you take the tubes from inside paper towel rolls, it turns out that they are not very highly-controlled, and you can usually find from any collection matching pairs where one will slide inside the other; you add two plastic lenses, and voila, you have an excellent telescope that kids can put together and use and learn all sorts of things.

And then we can illustrate important principles like the Doppler effect, which is used to determine things as diverse as the fate of the universe to the fate of drivers who are caught speeding; and we can just illustrate what happens when a whistle is moving, accelerating toward you and then accelerating away from you—just like this.

So with just very simple illustrations like this, plus a little lesson, which I won't give you, you can teach a lot, and it goes a long way. And we also believe very strongly that humor should be a part of teaching, and there is no reason why it can't be a strong part of science teaching, nor is there any reason—in fact, every reason the reverse—to isolate science from the other subjects. Science should be integrated with the other curricula, and can be.

Next, we have developed all these things—great—but there is utterly no purpose to it unless they are used. How do you get things used? That is not easy at all. We have adopted a several-tier approach.

First of all, we have developed the materials with teachers working directly with scientists, iterating, getting the stuff tried in their classes, coming back, finding out what the students like, what they don't like, why they don't like it and so forth. Then we have brought in teachers this summer from all over the country. We had 30 teachers from 18 different States, and we had them for three weeks at the Center for Astrophysics, where they learned all about these materials, how to use them, and are now testing them out in their school systems throughout the country.

But 30 teachers aren't very much, considering that we have something like 11,500 high schools in this country. So we have to have some way of multiplying the effect, and what we have chosen is to bring in teachers who agree as part of the condition that they come to our summer institute that they will train other teachers in their regions, a certain number each year, and by such a multiplier effect it is possible at least in principle to reach essentially all the high schools in the country.

We hope to have our first complete year-long course available for use in the school systems and suppliers for all these simple materials by the fall of 1992. It takes a long time. We have been at it for three years already. There are no quick fixes.

So that is what we are about. Now I'd like to just make a few general remarks, and then I will be delighted to answer any questions.

Virtually all aspects of the educational enterprise need reform. It is a monumental task. No one approach is going to solve all the problems. In fact, we probably couldn't even agree on a definition of what the best approach is. But what we should do are very careful, well-planned, well-executed and well-evaluated experiments to try to see what does work and what doesn't work. And this will take time, there is no getting around it.

Finally, we must make not only a wise but a massive and sustained investment; it has to be continuous. We can't just start every time there is a Sputnik and stop every time we have a matching satellite in orbit. We have to keep it up, and it is a massive and sustained investment of human as well as monetary resources. But we have to turn to it, and there is no time, as Carl said, as starting now.

Thank you.

The CHAIRMAN. Thank you very much, Dr. Shapiro.

[The prepared statement of Dr. Shapiro follows:]

PREPARED STATEMENT OF DR. IRWIN SHAPIRO

Science Education in the United States

Everyone talks about the weather, but no one does anything about it. Like Mark Twain's weather and ours, education is crucial to every citizen of this country. Like the weather, education poses enormous problems. But, unlike the weather, we can do something now to improve education. And we must.

Our society is becoming ever more dependent on science and technology. Citizens are called upon to decide issues with increasingly complex scientific bases. How do we respond to predictions of global warming, of dangerous depletion of atmospheric ozone, and of cancer-causing contaminations of our water supplies? How can citizens distinguish hype from solid evidence? Virtually everyone agrees that the level of scientific literacy in this country is deplorable. Test after test and poll after poll confirm the same conclusion. Anecdotal evidence is equally depressing. Our interviews of recent graduates of a prestigious university disclosed that all believed they understood why we have seasons on Earth, but the overwhelming majority was wrong. At the Harvard-Smithsonian Center for Astrophysics (CfA), we decided several years ago to tackle some of the problems with primary and secondary science education. We started with high school, working under the rubric of Project STAR -- Science Teaching through its Astronomical Roots (since astronomy was in many senses the first quantitative science). I will first outline the facts and assumptions that form the basis of our project, and then

describe our approach and progress to date. I conclude with a few general remarks.

Consider some relevant background facts:

1. Virtually all students, even before taking a science course, have developed preconceptions, usually misconceptions, about how nature "works".

2. High school science teachers are all too often ill-prepared to teach their subjects.

3. Most present-day high school science texts are densely packed with concepts and specialized jargon, making them difficult to penetrate by students and teachers alike.

Our program leans on these facts and many assumptions, including:

1. Student preconceptions must be dealt with directly.

2. Teaching a very few fundamental principles, and examining many different applications of each in straightforward language, will promote understanding and mastery of the basic building blocks of science; these goals should largely supplant the memorization of many (disconnected) facts and esoteric vocabulary (for "pressure-induced vorticity

oscillatory sound phenomenon" read "whistle").

3. Principles of science and mathematics can be taught effectively using examples from astronomy which take advantage of students' general fascination with the visual wonders of the universe.

4. "Hands-on" activities in which students build and use their own apparatus are more effective in dispelling misconceptions and promoting mastery than is almost exclusive reliance on the lecture technique.

5. Enthusiasm of teachers is a great stimulus to student interest in learning.

6. Humor helps.

7. Course curricula should be developed with active participation of teachers, and should be tested widely and modified accordingly.

8. Curricula should not be isolated, subject by subject; the interrelationships and interdependencies should be emphasized (for examples, between science and technology, between science and language, between science and economics).

9. Enormous inertia must be overcome for school systems to adopt new curricula.

10. Evaluation is a crucial component of any education project, and, to be a reliable guide, likely needs to go well beyond machine-marked, multiple-choice tests. Since long-term effects are being sought, of necessity a sustained commitment to evaluation is required.

We are developing a one-year course, with support from the National Science Foundation (NSF). We approach this goal by:

1. Gathering the facts of present-day high school science teaching through a questionnaire sent to all of the approximately 12,000 high schools in the United States, both public and private. We discovered, for example, that not even one single high school text on astronomy or space science is available in this country.

2. Establishing a partnership between scientists and teachers to develop, test, and evaluate the ideas for the curriculum.

3. Developing devices that illustrate the few basic principles to be taught, that can be built by the students, and that are very inexpensive, even when hi-tech. We already have

over half a dozen, ranging from a telescope more powerful than Galileo's, built from two paper towel tubes and plastic lenses, costing a total of about fifty cents, to a device for determining the distances to stars that consists of an ordinary flashlight, small pieces of scotch tape and aluminum foil, and a ten-cent piece of optical fiber. We are also developing a more powerful telescope system, dubbed the MicroObservatory, that could be within the economic reach of individual school systems and that would enable students to obtain "hands-on" experiences with a broad range of modern techniques, such as computer-enhanced image processing, and even to engage in research projects of significant interest to professional scientists, such as searches for new comets and undiscovered asteroids. Here a network of school systems could be involved in coordinated cooperative projects.

4. Inviting applications from teachers all over the United States to attend, with NSF support, a three-week, limited enrollment (30) summer institute at the CfA to train them in the use of the Project STAR materials for test in their classrooms. To train a nationwide cadre of teachers in the use of these new materials, we started this past summer a "chain letter" approach: teachers who attended this summer's institute, and following ones, will each train over the succeeding three years, of the order of 100 teachers in

their respective regions of the country. How many generations will be sustainable with this approach remains to be seen. Our intent, in addition, is to assemble a permanent network of master teachers who will be available to help others. Training institutes held so far have been enormously stimulating to the teachers. I was overwhelmed with the enthusiasm of these teachers and the inspiration they all felt working with professional scientists. The chain letter approach loses this direct contact in the following generations. This deficit could be repaired by utilizing professional engineers and scientists from regional industries and universities.

5. Working with publishers and school systems to enable the materials that seem to be effective in trials to be made available widely and to be used. We expect our one-year course to be ready for such distribution by the 1992-93 school year.

6. Evaluating the impact of our development. Since we are still in the testing stage, it is far too early, unfortunately, for discussion of impact.

So much for the status of our project. Is it the last word? By no means. Many different approaches to all facets of the education problem need to be tried in well-planned, well-executed, and well-

evaluated experiments. These will perforce take many years; effective shortcuts likely do not exist.

Efforts on a broad front are required, from pure research in cognition, or learning, to the most practical problems of recruitment of talented people for teaching, of establishment of certification standards, of motivation of students, and of provision of needed resources for school systems. We ignore any of these aspects at our collective peril.

The totality of problems that must be overcome in our nation to make education in general, and science education in particular, sufficiently effective to sustain our world position is staggering; decades will be needed to make substantial, demonstrable progress. These problems are probably most serious for minorities and, with regard to science and mathematics, for women as well. We must begin. And we must follow through. To do less would put in jeopardy the future of the nation.

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The CHAIRMAN. Dr. Lederman?

Dr. LEDERMAN. Thank you very much, Senator.

My partner and I are here to describe to you what we believe is a very dramatic plan for improving education in the Chicago public schools—and when we say "Chicago public schools", we'd like you to read Boston and Newark and Detroit and Oakland and New York and so on, because this is something that we hope would be adaptable to inner city schools.

In 1986, then Secretary of Education William Bennett characterized the Chicago school system as the worst school system in the Nation. Education seems to call forth vivid metaphors, but Mr. Bennett's characterization is probably accurate enough.

The initiative we are going to describe to you was triggered by Secretary of Energy Admiral James Watkins. Back in May of this year, I was Director of the Fermi National Accelerator Laboratory located in Batavia, Illinois. Fermilab is a single-purpose lab devoted to research in high-energy physics, about as abstract a science and as far from practical applications as you can get, rivalled only be extragalactic astronomy, probably, but perhaps in expiation for the guilt at being paid to work in a field we enjoy so much, the laboratory was very active in precollege science education.

I will append for your records a list of some of the many educational outreach activities that actually began as pure volunteerism and are now additionally supported by the National Science Foundation and the Department of Energy as well as foundations and individuals.

We deal with kids from K to 12, and we deal with their teachers. Most of our activities have reached a few thousand kids and a few hundred teachers, and deal with people mostly from the affluent suburbs of Chicago.

We were influential, with the help of Governor James Thompson of Illinois, in founding the Illinois Mathematics and Science Academy, a public residence school for gifted children who move to the school at the sophomore level and live there for 3 years.

A few weeks ago, it was announced that our first graduating class, the class of 1989, had scored number one in the Nation in ACT scores.

But now we turn to a totally different kind of world, and here is where Admiral Watkins enters with his challenge to the Department of Energy laboratories near Chicago, which is the Fermilab and the Argonne National Laboratories. And the question he asked was: What can DoE do to help the Chicago public schools?

What I would like to do now, in an effort to confuse your record as much as possible, is to call on Lourdes Monteagudo to tell you a little bit about Chicago before I give you the plan.

[The prepared statement of Dr. Lederman follows:]

PREPARED STATEMENT OF DR. LEON M. LEDERMAN

Mr. Chairman,

I am here to describe to you a dramatic plan for the improvement of education in the Chicago Public School system (CPS).

In 1986, then Secretary of Education William Bennett called the CPS the worst school system in the nation. Education seems to call forth vivid metaphors but Mr. Bennett's characterization is accurate enough. I would like to talk about a very bold initiative which was triggered by Secretary of Energy Admiral James Watkins. Back in May of this year I was the Director of the Fermi National Accelerator Laboratory located in Batavia, Illinois. Fermilab is a "single-purpose" laboratory devoted to research in high energy physics, about as abstract a science and as far from practical applications as you can get (rivalled only by extra-galactic astronomy) but perhaps in expiation for our guilt in being paid to work in a field we love, the Laboratory was very active in pre-college science education. I will append (Append I) to these remarks, for the record, a list of some of the many educational outreach activities that began as pure volunteerism and is now additionally supported by NSF, DOE as well as a number of foundation and individual contributions. We deal with kids from K-12 and we deal with their teachers. Most of our activities, which

have reached a few thousand kids and a few hundred teachers, deal with people from the affluent suburbs of Chicago. We were influential, with the help of Governor James Thompson of Illinois, in founding the Illinois Mathematics and Science Academy, a public school for gifted children who reside at the school for 3 years, from ages 14 - 17 in general. A few weeks ago, it was announced (Append II) that our first graduating class, the class of '89, had scored number one in the nation in ACT scores!

Enter Admiral Watkins and his challenge to the DOE laboratories near Chicago (Fermilab and Argonne National Labs): What can DOE do to help the CPS?

Since I was scheduled to leave Fermilab (in the affluent suburbs) on July 1 for a position as Professor at the University of Chicago, I had a special interest in finding out about the "... worst school system in the nation." I learned that there are 410,000 children in CPS, 88% minority, 12% white attending some 600 schools tended by about 20,000 teachers. In the spirit of Mr. Bennett's remark or even the more elegant but not less purple prose of Dr. David Gardner's now classic Nation at Risk (with his "rising tide of mediocrity...") I can assert that a large fraction of these 400,000 children were being written-off in this urban, poor, inner city that dominated the CPS. I listened to all sides of the problem: the often non-existent family support structure, the hazard of the streets, the state of disrepair of so many of the buildings, the lack of equipment.

One problem in particular loomed as paramount, stressed over and over by the various groups with which I met and that was the poor state of preparation of so many of the teachers in mathematics

and in science. How can you fire up kids who have managed to get to the school safely when the math teacher can't do fractions and cannot teach science at all? The ultimate tragedy is compounded when children arrive at the school ready to learn and knowing in some intuitive, child-wise sense that the teacher is just using time? There just can't be a glimmer of the passion of teaching - not because the teacher is lazy or uncaring - but because our system is delivering to the schools teachers very poorly trained in the substance of what they must teach and in the most effective ways of transmitting this knowledge.

So we concentrated on the teacher and we absorbed many of the ideas that were being tried by many dedicated people in the school system, in the outreach of the universities located in Chicago and in our own experiences at Fermilab and Argonne. We also became aware of an exhilarating change taking place in the CPS, school reform! Clearly I cannot detail the many positive steps which are now underway to restructure a system that failed. I can refer you to the Record for a speech by Senator Bob Kerrey (Nebraska) on October 13 which describes the Chicago reform lead by parents and citizens, by the University and business community, the teachers, the Mayor and Governor, all sectors of a now aroused community.

In the context of this reform we envisioned a new institution: we call it the Academy for Science and Mathematics Teaching and its function is to provide the enhancement in capabilities for that large fraction of 20,000 teachers involved in mathematics and science teaching. Building on tested programs which have worked for 5 schools here and 10 schools there, we have sought to blend our

experience in organizing and managing massive and essentially intellectual systems with the experience of teachers and scientists in the trenches. The details are still to be fine tuned and we append to this testimony (Append III) the abstract and executive summary of a preliminary proposal. Our approach is to treat with the teacher in the context of the school and, in effect, to set up a continuous interaction between the Academy and the teacher. A pre-service teacher would spend a year or more at the Academy, enhancing skills, learning and trying new methods. An in-service teacher would attend summers, weekends, late afternoons or during the week if substitutes can be found. All extra time would be paid. The Academy would be managed in the style of the National Labs by a consortium of Universities under contract with the Federal agency, presumably the DOE. It would serve as a focus for all the innovative programs that have been developed across the nation. The staff would consist of master teachers, university and laboratory scientists. As I stressed, an ethic of continuous retraining must be established as new technologies, new methods of cognition, especially as applied to the large black and hispanic ethnic groups are perceived and tested. Our plan has built in procedures for monitoring the progress of the students as we reach their teachers. It also includes the production of modest and simple kinds of teaching kits and equipment.

I have three final comments.

(1) Costs: The huge scale of the task and the urgency of the plight of 400,000 children dictate the cost which we estimate will

require a federal contribution of about $25 million a year, at least for the first 5-7 years. This increment (in purely economic terms) is a prudent investment designed to convert huge numbers of children, potential burdens on society (to the tune of tens of thousands of dollars per year each) to assets of trained minds and skilled hands desperately needed by our industries and laboratories. The cost must also be put in the context of the $2 billion spent in the City of Chicago. Federal dollars must be highly leveraged to be effective and clearly this is the case.

(2) To the question: Why science and math when reading and communication skills and geography are at least equally important? Obviously this is a correct question but I can offer this committee powerful data indicating that activity-based science, well-taught in the earliest grades - opens the door to the joy of learning. This is attested by extensive evidence (referenced below) that students so exposed do better in their reading, language and thinking skills than those using only textbooks.

(3) To the question of why Chicago? We assert that our plan is readily adaptable to all inner city - urban school systems - that it needs to be tried in one or two settings because we will make mistakes - and that CPS, with its scale - 410,000 students, 20,000 teachers - 88% minority - is the best deal the federal government can be offered. It also has the best chance of success because it will have the support, the commitment, the dedication of so many communities: two major national labs,

6

five universities, a very committed business community through their Leadership through Quality in Education committee, the citizens reform groups, the teacher's union, the Mayor and the Governor.

Conclusion: I have not seen drafts of any proposed legislation, Mr. Chairman, but it is my fervent plea that you put your considerable influence toward encouraging and assisting Admiral Watkins in his zealous efforts to provide this kind of demonstration. If we can begin to show results in our inner city schools, if we can begin to see minorities fully represented in our drive to restore and advance our scientific prowess, then I'll feel much better about the future of the nation.

The Effects of New Science Curricula on Student Performance

Shymansky, Kyle and Alport, Journal of Research in Science Teaching, 20 387 (1983)

Activity Science - Evidence Shows it Matters

T. Bredderman, Science and Children, Sept. 1982, p.39

APPEND I

The Science Education Center at Fermilab

October, 1989

Thank you for your interest in the Science Education Center (Center) at Fermilab. I have added your name to the mailing list for *Sciencelines* - a newsletter for educators published quarterly.

The Center is a collaborative effort between Fermilab and the education community. School districts will have an opportunity to become members of the Program Advisory Group. This group will play a role in determining the programs offered through the Center.

Three program areas are being developed: Teacher Resource Center, Formal Education Programs, Informal Science.

TEACHER RESOURCE CENTER (TRC). The objective of the Teacher Resource Center (TRC) is to generate a stimulating atmosphere for science education by providing materials and services to schools. The TRC will be hub of an education network in DuPage and Kane counties that will include interested science educators and school librarians. The TRC will be a clearing-house for ideas, materials and resources. It will house educational materials for inspection and evaluation by teaching professionals. A hotline will connect teachers to a resource database of professional scientists, teachers and others with expertise in science. Space will be available for teachers to build classroom demonstrations and assemble science kits from supplies provided at cost. Outreach activities, particularly at the elementary school level, will offer opportunities to teachers who might not otherwise have contact with Fermilab.

FORMAL EDUCATION PROGRAMS. Since 1980 Fermilab has been offering science education programs for precollege students and teachers. Currently, the following programs are offered:

High School Programs: **Saturday Morning Physics**, a 10 week lecture series, is offered to 100 students three times a year. Each Saturday students hear a lecture by a Fermilab physicist, participate in small group discussions with post-doctoral students and tour part of the laboratory. Students who attend seven of the lectures receive a "diploma" at a ceremony attended by their parents. **Target: Science and Engineering** is a six week summer apprentice program for gifted minority students. Half of their time is spent on the job and half is spent in the classroom conducting an individual science project. Students present a research paper to their colleagues, parents and supervisors at the end of the summer. Fermilab participates with other Department of Energy (DOE) national laboratories in **The DOE High School Honors Research Program.** Students from each state, Puerto Rico, the District of Columbia and from the six Economic Summit countries attend the two week program. In the mornings the students attend seminars with Fermilab scientists who present a modified version of the Saturday Morning Physics curriculum. In the afternoon small groups of students are assigned to current experiments where they work along side graduate students and scientists. Each experimental group presents a paper on their work.

Six programs are offered for high school teachers. The **Summer Institute for Science and Mathematics Teachers at Fermilab** is the original program sponsored by Friends of Fermilab. 45 high school science teachers in biology, chemistry and physics and 15 mathematics

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teachers attend the four-week program. Morning lectures by research scientists and mathematicians are presented in the four disciplines and in plenary sessions. Afternoon sessions include computer, laboratory and mathematics sessions with master teachers. Four follow-up sessions are held during the academic year. Participants receive a stipend and can earn graduate credit for successfully completing the program. The program which has served 255 teachers is currently funded by NSF. **Chemistry West** and **Physics West** are teacher networks that hold monthly meetings during the school year for participants to share skills, teaching strategies and materials for high school science classrooms. A physicist and a master teacher are available upon request to give a **Physics Mini-Course** in particle physics or cosmology based on the format developed in the Summer Institute. Courses have been given in Pennsylvania, Florida and Mexico City and are scheduled in Wisconsin and Texas. **Topics in Modern Physics** brought a group of 26 high school physics teachers to the Laboratory to develop curriculum materials and design a regional inservice program in modern physics topics. The teacher resource manual is available at cost. The program was funded by NSF. Fermilab participates with other DOE laboratories in the **DOE Teacher Research Associates Program.** Some twenty teachers are assigned to work with a scientist or engineer on a research project during the summer. Teachers are selected from both regional and national pools. Regional participants are nominated by their principal. National participants are nominated by their state education departments. Employment selection is made by laboratory supervisors. Participants learn to acquire data and report results in a scientifically acceptable manner, skills directly transferable to the classroom.

K-8 Programs: K-8 programs began in 1984 with the publication of **Resources for the Science Classroom**, a computer database and resource book of over 150 listings of people, programs, tours, materials and give-aways. The second edition is available free of charge. Then, following the recommendations of a needs assessment workshop, two programs were developed to bring students and their parents and teachers to Fermilab: **Beauty and Charm at Fermilab**, a hands-on curriculum unit was developed, and teacher inservice workshops continue to be offered. Students in grades six to eight who have studied the unit may tour Fermilab and visit with a scientist. Over 90 teachers have been trained in the program and some 1300 students visit the Laboratory during the school year; **The Wonders and Magic of Science** is a science show for outstanding area science students in the third to sixth grades. Initially, this program was offered as the culmination of a poster contest with local schools sending winning posters and their artists to a final competition at Fermilab. The program has been revised to let the schools select students in a variety of ways and has grown to include two shows with a combined audience of some 1200 students and parents. Three presentations have been developed to model effective teaching methods and offer successful classroom demonstrations. **Weird Science**, a chemistry program, and the **Cryogenic Magic Show** and the **Electricity Magic Show**, physics programs, are scheduled as inservice programs for teachers and as classroom demonstrations for students. These programs reach over 5000 students and teachers each year. **Hands-on -Science**, the latest FFLA project, is a traveling collection of interactive activities with accompanying teaching materials. The collection will be available for loan to schools during the school year.

Materials Programs: A variety of classroom materials have been developed in conjunction with precollege education programs. These are made available free of charge or at cost to teachers. Included are Beauty and Charm kits, Topics in Modern Physics Resource Books, videotapes, and posters. Some of these materials have been translated into Spanish and are made available to Latin American scientists and teachers.

INFORMAL SCIENCE

Hands-on science that encourages creative investigation and thoughtful questions leads to a real understanding of science and its applications and implications. Interactive exhibits, environmental exhibits, audio-visual materials, computers and a science playground will all be part of the Center's informal science offerings. The interactive exhibits will be developed in five areas: accelerators, detectors, scattering experiments, the structure of matter and the structure of the [illegible] will include table top interactive displays in many areas of science and

APPEND II

Chicago Tribune

FOUNDED June 10, 1847

STANTON H. COBB, *Publisher* JOHN W. MADIGAN, *President* JAMES D. SQUIRES, *Editor*

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22 Section 1 Wednesday, November 1, 1989

The test of investing in excellence

"Incredible! Just incredible! Wow!"

—Leon Lederman

So it's not quite the exhibition of erudition you'd expect from a Nobel Prize winner in acclaiming the Illinois Mathematics and Science Academy for its latest accomplishment. But it says it as well as any.

Lederman, a 1988 Nobel laureate for physics, former director of Fermilab and driving force behind the founding of the school, had reason to be enthused. His brainchild and its first graduating class of brainchildren recorded an average American College Test score of 29.5, the best of 5,856 American high schools.

It is expected that the students would do well on such things as the ACT; they represent a distillation of the brightest high school students in the state. But this is No. 1 in all these United States in a test taken by 1.38 million students, and their composite score was a whopping 2.3 points higher than the second best. And the test scrutinized not just their specialties, but the disciplines of English and the social sciences as well.

With all their other academic triumphs of the past year, including an astonishing 56 of the 168 graduates becoming National Merit Scholar finalists, it is a tribute not only to their brightness, but also to the degree to which it was cultivated at the school. It is a tribute to the school systems that spawned them. It is a tribute to the wisdom of Gov. Thompson and the General Assembly for creating the academy in 1986, and—despite a temporary lapse of faith over funding—a testimony that the state's money has been well spent.

The mission from the start for the Aurora school was to nurture the minds of the most promising students in Illinois—especially in the rigors of science and mathematics—the better to prepare them and the state to compete in a technologically competitive world. It was a bold gamble and bold experiment, a declaration that the state had as much an obligation to invest in its gifted students as its disadvantaged.

Now, with the first class off to college, the measure of that experiment can be exalted in one word: Wow!

APPEND III

A PROPOSAL TO THE DEPARTMENT OF ENERGY FOR AN ACADEMY FOR SCIENCE AND MATHEMATICS TEACHING FOR THE CHICAGO PUBLIC SCHOOLS

ABSTRACT

We propose that the Department of Energy fund an Academy for Mathematics and Science Teaching (Academy) for the Chicago Public Schools. The program will enhance instruction by updating teachers' background in basic subject matter and exposing them to new resources and teaching methods. The Academy will have a Resource Center, follow-up programs in the schools and outreach programs with area museums, national laboratories, universities and colleges, and industry. Taking the DOE national laboratories as a model, the Academy will be run under contract to the Department by a consortium of interested parties, with a Director chosen by a Board of Trustees.

NB This is a draft to convey a concept. It is compilation of ideas and suggestions from a large number of people who have been involved in the Chicago Public School project. The initiative of the Secretary of Energy to the Directors of Fermilab and Argonne to address the question of what DOE can do in the CPS resulted in a series of meetings out of which this concept emerged. Many details have yet to be debated

I. EXECUTIVE SUMMARY

The mission of the U.S. Department of Energy (DOE) includes as an essential ingredient, contributions to the scientific education of the youth of America as potential scientists, engineers, technicians and literate citizens who can understand the technological issues facing the nation. To this end, we propose that the DOE fund an Academy for Mathematics and Science Teaching (Academy) for the Chicago Public Schools (CPS.) The Academy will be a self-contained institution, responsive to the needs of CPS and managed by a Director who reports to a Board of Trustees representative of all interested sectors of the Chicago community. It will serve as an advanced training center for new teachers just entering the CPS system. Here, apprentice teachers will be in residence for up to two years in order to (1) establish an adequate command of mathematics and science subject matter and (2) advance their ability to communicate these important subjects to their students.

The Academy will also begin the process of enhancing the professionalism of mathemanics and science teachers who are already teaching via five to six week summer programs and monthly follow-up activities during the school year. If the Academy is staffed adequately, graduate credits including earning a Masters Degree will be arranged in collaboration with Chicago area universities. In special cases, regular teachers will be rotated into the Academy as instructors or as students depending on the needs as determined by school principals.

The mandate of the Academy is to improve the quality of mathematics, science and problem solving instruction for all 430,000 CPS students. The Academy will be the contact point for Argonne and Fermilab, area universities and colleges, and museums to join the effort to assist and support CPS educators. Through the Academy programs that enhance instruction and facilitate teacher and student contact with scientific and technological developments will be implemented as a coherent part of the CPS curriculum.

In order to have the greatest impact on the schools, this project focuses on the classroom teacher who, as a model, motivator and mentor, is the single most important component in the education process. Teachers are the catalysts of the learning process and must be adequately prepared, highly motivated, highly professional, and appropriately recognized and rewarded.

We envision that the Academy will provide:

- Provide advanced training of teachers to insure thorough mastery of subject matter and communication skills. This applies to both pre-service and in-service teachers at elementary and secondary levels.

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- Conduct a research-based program which leads to the development and effective implementation of new mathematics and science curricula and instructional methods. Particular emphasis will be given to curricula which integrate the teaching of mathematics and science.
- Make maximum use of the many programs which have been used effectively on a modest scale. (See Appendix). This dictates a focus on the entire school as the locus of change.
- Facilitate the involvement of scientists and mathematicians in the activities of the Academy. They will come from area universities, colleges, national laboratories, industrial research labs and museums. The activities will include staff development, materials development (hardware and software), and far-ranging interdisciplinary study of the science teaching process. Extensive use of sabbatical leaves will be necessary.
- Provide a focus through workshops and meetings to foster the collegiality of teachers, scientists, principals, museum directors and, in short, all parts of the mathematics/ science/education community.

The Academy is a teacher resource center that includes classrooms, laboratories and a library of instructional materials. The staffing of the Academy is fundamental to the success of the idea. We envision a core staff of master teachers supplemented by teachers on sabbatical and a strong contribution from professsors at Chicago area universities, scientists from Fermilab and Argonne and staff from science museums. The management of the Academy will be by a consortium under contract to DOE much as a national laboratory such as Fermilab is run by a consortium of universities (URA.) A Board of Trustees will set over-all policy and hire the Director. Again, using the national laboratories as a model, there will be a program committee reporting to the Director and a visiting committee reporting to the Board of Trustees.

It is our conviction that if the Director is well chosen, and if he or she maintains excellent communication with the principals, the Academy will evolve; it will devise new techniques and new missions. In this sense, our vision is literally pro-visional. The detailed steps presented in what follows are to be interpreted as suggestions for the kinds of activities which would fulfill the mandate of the Academy.

The following criteria were applied to develop a proposal that would make the most valuable contribution to CPS. The DOE contribution should:

- Make a long-term impact on the quality of mathematics and science instruction.
- Benefit *all* the students in the system.
- Be a model that can be followed widely across the nation.
- Be a coordinated part of the overall plan for school reform in Chicago.
- Result in a self-sustaining support network for mathematics and science teachers.
- Be related to the DOE national role.

Ms. MONTEAGUDO. Mr. Chairman, I would like to thank you for inviting me to be here. Dr. Lederman and I have been working together in Chicago trying to get this plan off to a great start.

I'd like to give you a little background on the city and what is happening there so that you can have some context in which to use the information that Dr. Lederman will be providing.

I am the Deputy Mayor of the City of Chicago for Education. My title, however, would mean very little to you if I don't tell you that I am a former teacher, I am a former principal of the city; I am also a former limited-English-proficient student who arrived in the city when I was 12 years old, having been born in Cuba—I am a Cuban American—and having reached the city as a minority without the full blessings of the English language, and thus have had the experiences of many of our children.

I have worked for the last 2 years in a grassroots movement in Chicago that basically took over the school system this last October 12th. We call it "school reform, Chicago-style".

If you wonder why I did such a thing—and not only myself, but many thousands of people in Chicago—let me explain that I am also a mother of two children in the Chicago public schools, in the Westtown Humboldt Park area of the city, which is equivalent to New York's Spanish Harlem.

In all of these roles, I have been an eyewitness to the disgrace of our school system. I am here today, however, in spite of that school system, representing the great Mayor of the City of Chicago, the seven interim board members who have been charged with turning around the system, 3,240 parents, 1,080 neighborhood leaders, 1,080 teachers, who were elected to what we call the local school councils, in an unprecedented effort to rescue our 410,000 students and the 29,000 teachers who work in the school system. And as you have heard, we were blessed by Secretary Bennett when he described us as the worst school system in the Nation.

Chicagoans from all walks of life, all races, ethnic origins, have managed to put aside personal agendas, economic and political agendas, to rally around our children and together bring down the wall that has been dividing their futures for so long, the wall that threatens the future of our city and, we believe, the future of our Nation, and that is the wall of ignorance.

Chicagoans have come to the understanding that ignorance and not communism is the greatest threat to our democracy. And for the record I would like to point out that we started doing that before the East Germans, who just took down their wall, except that we haven't gotten as much publicity; and certainly I can imagine that we'll be sending them some help, and I hope that something happens with us in Chicago as well.

When I said that William Bennett blessed us with calling us the worst school system in the Nation, I really meant that because sometimes it is not until we hit rock-bottom that we are able to really take a good look and decide to act.

As I told you, our school system services 410,000 children in 628 attendance centers, meaning schools. The population is 12 percent white, 59 percent black and 26 percent Hispanic, and of this population, 73 percent are poor and disadvantaged.

Of our 620 buildings, more than half of them are 50 years old, and more than 50 buildings are over 100 years old.

The citywide dropout rate is 43 percent, with the percentage increasingly proportionately with the number of minority children in the schools, topping it at 75 percent in Hispanic areas. Of the graduates, only one-fourth can read at the twelfth-grade level.

Historically, in our city as well as in our Nation, schools and school improvement initiatives have catered to a few students who seem to be most capable—the gifted and the talented, or the bright-eyed, bushy-tailed children who come to school already able to read. These children have support systems at home and at school. For these children, we lower class size, we equip their classrooms, we give them opportunity for hands-on experiences, we assign them our best teachers and specialists, we enhance their curricula with enrichment programs, we expose them to the latest technology, starting in preschool. When they have difficulties, we tutor them, and of course, we hug them, we spoil them, we counsel them, we shelter them from failure. And of course, we applaud them when they succeed.

These privileged few are only two percent of the schools' population—9,200 students of 410,000 in grades K through 12. For the thousands of others, their experiences are very, very different. I was one of those children. For these children, schools and their classrooms have been the most neglected unit of the school system, with inadequate buildings, old structures that are poorly equipped, with as many as 45 children in a mobile unit. And if you don't know what a mobile unit it, it looks like a sardine can next to a school building, and you learn what that feels like. These children wait, hidden like diamonds in the rough, their minds waiting to grow and to be discovered, waiting to be exercised in this place we call school.

These children are exposed to limited experience, usually concentrated to reading out-of-context and in endless drilling of arithmetic facts, usually paid for by our Chapter I funds.

When they ask questions, they are told that the answers are in the book. When they fail to demonstrate that they have learned, they get a big, fat "F"; and their parents are called and told that they should teach them at home. Now, question: If the teachers could not teach them, why should the parents be able to do it any better? And if they can, why should we have this place called school?

The only hands-on experience they receive is the copying of meaningless facts from blackboards, presented to them by teachers who lack confidence and content knowledge. Ironically, these ill-trained teachers are the ones left to instill in the children confidence, excitement and respect, love for lifelong learning.

Thousands of these children never have a class called "science." "What is the use," the teachers will argue; "They can't read the science book. Many of them can't even speak English. How can I teach science?"

For those who are actually scheduled for such a class, science is something you read about, you know, something about the stars and blood types and volcanoes and dinosaurs, and you know, the

inventors, Newton and Einstein—yes, and the solar system, something and the planets.

And for math, third grade is memorization of multiplication tables; and fourth grade is boring long division—God forbid we use a calculator—that is cheating, you know.

Children and parents are left to their own resources, to take up for what the schools and the so-called professionals cannot or will not deliver—quality education.

Chicago has realized that a few successes cannot make up for thousands of failures. Our children are crying for help very much as they did when they were babies and they cried when they were hungry.

Spiraling dropout rates, demoralized teachers, gangs, drug abuse, declining student achievement—these are the symptoms of the cries for help coming from our schools.

Instead of building self-esteem in our children, we fail them drastically. We frustrate them before they get a good start. Then they carry feelings of failure for the rest of their lives, and we wonder why they rebel and why they drop out.

The place called school must not be a place where children learn to fail. They must be places where highly-skilled adults help children learn by coaching them through experiences that will develop in them the love of learning that needs to be internalized. If they are helped to learn and thus feel success, they will be motivated to learn some more. And maybe if we do it right, we can get them to tackle what most children and young adults consider themselves most incapable of attaining—mastery of science and mathematics; the keys to critical and abstract thought; the understanding of our world and our environment as well as the wonders of our existence.

But who is going to teach them? Who is going to teach and coach our children? And what are we going to teach them?

On any given day in Chicago, we have 425 rooms that go uncovered by a human being called a teacher. We cannot find enough substitutes. We cannot find enough teachers. Of those who are teachers only 19 percent have a science or math endorsement, and most of these are already assigned to high schools or to schools for the most able. This last week, the Chicago Board of Education published a shortage of 2,000 teachers in our system. That means fundable positions that go without having a teacher in them.

If we are truly going to do a better job of teaching the children, then we must invest in the professional development of those who are charged with that responsibility—the teachers. Many of our teachers are also diamonds in the rough, waiting to be polished and discovered, never receiving the opportunity to learn enough to be able to teach. How can you teach something you know nothing about? Some will never be flawless diamonds but certainly can be helped to shine if a skilled hand polishes them; and yet others might seem like diamonds, but when you put them to the test, they can't scratch glass.

We must invest heavily in the pretraining, training and re-training of teachers. We must coordinate the pretraining programs in our universities with our new vision. We must access and offer curricula that have been developed and proven successful to work with our children and use them as part of the core of what we offer

in the school system and not in the periphery. We must give teachers the necessary teaching tools and environments that will allow science and math to become concrete and alive. We must organize the resources that circle our school system—and in Chicago we have many; we have the museums, the universities; we have people who are paying for private support programs. In this manner we can maximize our resources and bring in the necessary tutorial help that our children need.

To this end, Chicago has proposed an initiative to the Department of Energy which we will be requesting your support on. And under the great leadership of Admiral Watkins, and using our two flagships, Argonne and Fermilab, we know we can make things work for our Chicago children.

Dr. Lederman will tell you a little bit more about the academy, so I am not going to go into detail. But you have to understand that our direction in Chicago is very clear. We are committed as a city, from all walks of life, from all sectors of the city, to fundamental restructuring of our school system. We are committed to the redirecting of resources to where they are needed most—in the classrooms—to upgrade the quality of teaching by providing our teachers ongoing opportunities for professional growth.

Given its historical absence and the critical need, science and math initiatives should be the first to be addressed.

What is different about us is that we cannot continue—and I have in my speech here the same expression that we have already heard—to tinker around the edges. We can no longer afford to invest in programs that touch a small percentage of the student population or the teacher population. One teacher alone in a building will not change what happens to the children in that building over 8 or 12 years.

Most of what has been done has been done on a very small scale. We must now use all the resources that we have, all that we know, and we must make them available to all the children of the school system.

We need to bring about changes in every one of the schools. We are clear that parity must be achieved and that an intense focus must be placed to guarantee each and every child not only the same quantity of years in school but also the same quality of instruction.

Yes, Chicagoans are very idealistic, but we are also very realistic. We know things cannot change over night, and we are in it for the long haul. We must sustain and monitor the efforts until the retraining, the restructuring and the repositioning of our resources allows for the innovations to become the core programs of our school system.

We are focused, systematic and inclusive. We are assuming responsibility for our children's failures, and our sense of urgency commands that we reach out to all possible investors.

A problem of this magnitude cannot be funded with bake sales. There is no other national emergency that we would do such a thing with.

Just to give you one or two specifics on other things other than the retraining of teachers, and specifically in this case would be the science and math—just to be able to prepare our buildings for

children to be able to learn, we have an estimate of $1 billion just in physical improvements that are needed in the city; $6 million for asbestos removal, $530 million for major repairs and improvements, including painting of buildings that have not been painted for over 20 years. We need to build 1,712 classrooms, at $370 million.

The problem is tremendous. This we see in the field of science and math; basically, you can talk about any other subject matter, and you will find the same problem. So it is of tremendous magnitude, but Chicagoans are going to move.

Dr. Lederman is going to tell you about the deal we have with the Department of Energy.

Dr. LEDERMAN. Thank you.

We clearly interpreted our mission to be something that was feasible that the Department of Energy could do within the context of its general programs and its responsibilities to ensure the search and energy future of our Nation and our need for an influx of trained people, so clearly it is within their mission to look at this. And Lourdes used the word "flagship"—for the Admiral, flagships are very important. He had these two "battleships" in Chicago, as most admirals have globes in their offices, and some dot that is labeled "Chicago", and two flags or the two big national labels. And he said, "What can my battleships do to help?"

We tried to come up with a reasonable proposal in this both depressing, as Lourdes described to you, but also exhilarating atmosphere of revolutionary reform.

Well, what we envisioned was a new institution which for the moment we call the Academy for Science and Math Teaching—perhaps we should call it the Laboratory for Science and Math Teaching—and its function is to provide the enhancement and capabilities for that large fraction of 29,000 teachers who are involved in mathematics and science teaching. And concentrating on the teachers, we mean to raise the achievement of all of the 400,000 children so that they can compete successfully with any school system in the world.

Now, in finding out what is going on in Chicago, I found an enormous number of activities, somewhat similar to the activities that Irwin Shapiro described, ideas, where university people are involved in the city, trying new things, integrating math and science instruction. There are five very active universities in the City of Chicago, and every one of them was reaching out and trying different kinds of things. So we wanted to build on these many well-tested programs that have worked for five schools here and ten schools there, and we thought to blend our own experience in organizing and managing massive and essentially intellectual systems, like building particle accelerators, to blend that experience with the experience of the teachers and the professors at the universities who have been in the trenches.

The details of our proposal are still to be fine-tuned. I have appended to this testimony an abstract and executive summary of a preliminary proposal. But the approach is to treat with the teacher and to treat with the teachers in the context of the school, and in effect to set up a continuous interaction between this academy and the teacher.

Pre-service teachers would spend a year or more, whatever it takes, at the academy, enhancing skills, learning and trying new methods, becoming familiar with all the tricks of small, inexpensive equipment, stressing for the earlier grades the hands-on experience. And in fact, the preservice looms as a more and more important part of the system as we realize that a very large fraction of the Chicago teachers will be retiring in the next 5 years or so.

An in-service teacher would attend summers, weekends, late afternoons or during the week, if substitutes can be found. All extra time would be paid. In other words, the preservice teacher would be paid entry-level teaching but would not teach, would stay at this institution and learn what to teach, the substance matter, and learn the latest exclusions, the latest progress in how to teach science and mathematics.

The academy would be managed in the style of a national lab, by a consortium of universities under contract with a Federal agency, presumably the Department of Energy. It would serve as a focus for all the innovative programs that have been developed across the Nation. The staff would consist of master teachers, university and laboratory scientists.

As I stressed, I think it is important that there is an ethic of continuous retraining. Teachers cannot be taken in for 6 months or 1 year and then abandoned. We have to keep calling them back and finding out what their experiences are and giving them the newest methods of cognition and teaching of science.

Our plan, of course, has built-in procedures for monitoring the progress of the students as we reach their teachers. It also includes the production of these modest and simple kinds of teaching kits and equipment that Irwin so dramatically illustrated.

I have three final comments. On costs, well, it is the huge scale of the task and the urgency of the plight of 400,000 children that dominates the cost, and we estimate that it will require a Federal contribution of about $25 million a year, at least for the first 5 to 7 years. This increment, in pure economic terms, is a prudent investment designed to convert large numbers of children, potential burdens on society, to assets with trained minds and skilled hands, desperately needed by our industries and laboratories.

The cost has to be put in the context of the $2 billion spent in the city of Chicago. Federal dollars in this problem must be highly leveraged to be effective, and clearly this is the case.

To the question why math and science when reading and communication skills and geography are at least equally important, these are obviously good questions. To the committee, I can offer powerful data that indicates that this hands-on, activity-based science, well-taught in the earliest grades, opens the door to the joy of learning. This is attested by extensive evidence which I have referenced that students so exposed do better in their reading and their language and thinking skills than those using only textbooks.

To the question of why Chicago, that's the point we made to the Admiral. Admiral, we said, do we have a deal for you. We have the worst school system in the country. We have 88 percent minority. We have a 45 percent dropout rate. No other city can offer you these advantages.

It also has the best chance of success now because this program will have the support, the commitment, the dedication of so many communities, two major national laboratories, five universities, a very committed business community, citizens' reform groups, teachers' union, the mayor and the governor.

I haven't seen any drafts of the proposed legislation, Senator Kennedy, but it is my fervent plea that you can put your considerable influence toward encouraging and assisting the Secretary of Energy in his zealous efforts to provide this kind of demonstration.

If we can begin to show results in our inner city schools, if we begin to see the minorities fully represented in our drive to restore and advance our scientific prowess, I'll feel much better about the future of the Nation.

Thank you.

The CHAIRMAN. Thank you very much. It really sounds terribly exciting.

Just to start with, Dr. Lederman and Dr. Shapiro, you are enormously successful, skilled, talented researchers, teachers, writers, and speakers. How realistic is it to expect other scientists, researchers, teachers to do the kinds of things you people are doing? It must take a lot of time away from your whole research program. How likely is it that we could get others to do it, and how important is it that we do?

Dr. LEDERMAN. I think I already mentioned that a very large number of scientists are getting involved in this. I think it is important to understand that the color of your hair plays a big role in all of this; that we want to keep our young scientists in the laboratory. That's where they belong. But when you get on a little bit, and it is hard to see the numbers on the dials and so on, then maybe you can spend some time doing other things.

The CHAIRMAN. That probably applies to politicians, too. [Laughter.]

Dr. SHAPIRO. Actually, it turns out there is an effect even more important than the color of your hair, and that is the age of your children. When parents start seeing, like I did myself—I saw the chemistry book my daughter brought home from school. I looked at it, and I was appalled. There they were, talking about molecular orbitals, and she didn't have the slightest idea what a wave was—that may not mean much to you, but some of my colleagues here will understand—and that gets people interested, I think, even more than the color of their hair.

But I would say as far as scientists 'involvement is concerned that those who are willing to devote a large fraction of their effort to this endeavor probably correlates well with the color of their hair, but that people of all ages in science want to and feel motivated to do something, I think is clear from my experiences.

What we need are structures and programs within which they can interact with teachers and students. I think it is unrealistic and probably would be counterproductive to have scientists in the major parts of their careers devoting all their efforts to organizing such programs and setting them up. But if we have the structures and the programs, then they can contribute and can contribute well.

The CHAIRMAN. I understand. It is a question of providing some vehicles so that they can devote some of their energies toward these kinds of educational purposes.

Let me ask you, Ms. Monteagudo, are you a supporter of the bilingual programs?

Ms. MONTEAGUDO. It all depends on how they are implemented. The whole theory of bilingual education is sound if you know how to implement it—the same problem we just talked about, where people are being put in the classrooms not knowing what they are supposed to be doing with that concept, then makes the bilingual education program seem like it doesn't work over time. But the real problem is that it has never been implemented, because the people you are putting in front of those children have not been trained to do what you are asking them to do. It is exactly the same problem.

The CHAIRMAN. Given the fact that we've heard a wide range of different suggestions—and I certainly agree that we are going to have to approach it from a multidimensional point of view, and we have to be in it for the long haul—but given where we are resource-wise—I know you were probably here in the early part of the hearing when we were talking with Senator Hatfield about that, and we are going to do the best we can—where should we be starting off in terms of the Federal role? Where should we be putting whatever energy or resources that we can? Can you give us some kind of reaction to that?

Ms. MONTEAGUDO. Basically, I feel that you have to put money into training of teachers in all of the different areas. I think it was said very well by Dr. Malcom that it has to be a partnership between the Federal, State and the local level. It would be of no use for you to give money, let's say, for the retraining of teachers to a school system at this point that is not willing to recognize their own problems from within the system. You have to sort of match it up. But once you have identified a school system that is really into changing it for children, then you must have the support systems to be able to train the teachers, because we know that is a problem; to upgrade the quality of the places we call school; to look at the textbooks we are using and actually make some major decisions, which are going to make a lot of people unhappy, because those textbooks are businesses and livelihoods for some people, to look at them and make decisions on what you are going to buy and what you're not going to buy. So it depends—

The CHAIRMAN. Let me just interrupt you. I'm talking just in the area of science and math. Clearly, you need to have a competent person to be able to teach that, so it is relevant in that sense. We have tried in our other legislation to try and really focus on a variety of different things that can enrich the whole experience—because you know, half the teachers drop out within the first two years—mentoring and the wide variety of different things, sabbaticals for high school teachers—all of which I think make a great deal of sense. But if we accept that we are going to try and do some of that, what do you think we really should be or can be doing in terms of getting the most bang for the buck from the Federal Government?

Dr. SHAPIRO. Well, I think you are absolutely right in your implication. The Federal funds have to be used in a highly-leveraged way. As one example, curriculum development. We could, for example, produce one course with a lot of hands-on activities and so forth, and then that can be used throughout the country, with the Federal Government providing the seed money to do the development and then the rest of the country taking over the purchasing of the texts, the using of them, and so forth. So this kind of model where the Federal Government provides an essential ingredient that then can be utilized and built upon by the States and local areas I think is a proper role model.

Dr. MALCOM. I'd like to just offer a number of places where a small investment can make a difference. Let's just start at the upper levels and work our way down. If we would but, for example, add the money for a single undergraduate, a minority, for example, to the research grant of an active researcher and get that student in by the sophomore year, to know what the culture is like and to turn them on to research and the possibilities that are within research, we have a shot—for what is maybe less than a $2,000 investment, we have a shot for holding that student.

If we take, for example, the whole issue of chapter moneys, right now I would say that the chapter moneys that would go into Chicago are probably pretty considerable. There is nothing in the current regulations that says you cannot use the Chapter I moneys and the like to be able to empower them in terms of science and mathematics, the teaching and what-have-you. There are proposals that are floating around that talk about allowing the commingling of money that would be targeted. Now, this would be easy in a place like Chicago where such a large percentage of the students are already Chapter I-eligible, where you can provide more moneys that go directly to the site if you allow for flexibility and a certain amount of deregulation, and as the provisions of those proposals call for, that the same kind of commingling must be allowed with the State and local funds that are also in those categories, which means you increase the buying power of those dollars.

I think we can provide much more from the existing funds that we have, and we need to look at them that way. We have the moneys in the Eisenhower program, for example, that are going into our States and our localities.

In all the cases, those moneys are not necessarily well-used because people are reinventing the wheel in many cases with those moneys. If we had a technical assistance center—not just a clearinghouse where all the good things were—but someplace like an agricultural extension model where you could get help, where people could interpret between the research and what it says about misconceptions or about learning or about how people learn, and they could make that interpretation to practice—how do you get from one place to the other; how can you manage that whole system. I think that there are opportunities already within the budget, but I think we have to start being creative about where the places are that we can actually make an impact.

The CHAIRMAN. Dr. Lederman?

Dr. LEDERMAN. Yes, I agree with everything everybody said. Leveraging, of course, is very clear. Education in this country is a

$380 billion boulder, and you've got to have a long stick if you are going to move it.

I am impressed by the success of the national laboratories, which I sort of grew up in and used all the time and then managed one. That model seems to be very effective. So as an example, we take this particular scheme that we are trying to formulate, and we try it, and we make our mistakes, and we correct them, and you now say, I'm going to apply this to 20 cities—most of them will be smaller than Chicago—you are talking about a $200-$300 million investment in national laboratory concepts in the cities in science and math education. That is a very small amount of money, I think. If everything you've heard today amounts to a threat to the well-being of this Nation, it is an increasing threat and one that should be contrasted with a decreasing threat which is costing us $300 billion a year. It is clear that these are things that we can't afford not to do.

Let me make one final comment. You asked Carl Sagan how can we sustain this drive toward better science and math education. In fact it is interesting that we lived through Sputnik; there was a great flurry of things, and we all took time off from our labs and wrote textbooks, and we were very excited about this, and 5 or 6 years later it was all gone.

This particular drive you could say started with the famous "Nation At Risk" document of David Gardner, with its purple prose and its "rising tide of mediocrity". It is sustained; we are still going on that. So it is at least 5 years old.

I think part of what sustains it is the fact that we are galloping toward the 21st century, and science and technology loom as an important part of our society. And the threat that I see most dramatic, which Carl referred to, is the environmental threat. These are terribly terrifying problems which are going to require an enormous amount of new science and new mathematics to deal with. And that is going to be with us for a very long time. I think that alone will sustain this.

One of the greatest futurists of all times, H.G. Wells, wrote 70 years ago—this might be a theme—"Human history becomes more and more a race between education and catastrophe."

The CHAIRMAN. That is probably a pretty profound way to wind up our hearing here.

Let me mention to Dr. Lederman and Ms. Monteagudo, Senator Simon wanted to be here. As you know, he is one of the really important leaders in education and enormously interested in this area and really an important thinker and ally of this committee in developing our education policy. As you know, he is floor-managing assistance for Poland at this very moment; so he regrets he could not be here.

I want to thank you all. We are going to develop the legislation—agreeing that we ought to be looking at the various experiences which are successful so that we can enhance them, and looking at ways that we can leverage resources in the directions which have been outlined here. We are going to need a lot of help and assistance, and this has been a very important and useful hearing this morning in giving us many ideas to move us down that road.

I want to thank you all very much.

The committee stands in recess.
[Whereupon, at 12:10 p.m., the committee was adjourned.]

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